MSRI
Mathematical Sciences Research Institute

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Final Report, 2005–2010
and
Annual Progress Report, 2009–2010
on the
Mathematical Sciences Research Institute
activities supported by
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October, 2011

Mathematical Sciences Research Institute
Final Report, 2005–2010
and
Annual Progress Report, 2009–2010

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Summary of Scientific Activities at MSRI between 2005 and 2010

Here is a brief summary of the scientific activities that were held at MSRI during the 5-year period of the DMS grant #0441170. For each of the activities, details can be found in the annual reports. Note that the annual report for the last year of the grant, 2009-2010, follows this summary.

Programmatic Activities

A major program at MSRI, which runs for either a single semester or an academic year, brings 30 to 45 long-term[1] visitors to the Institute at a time, ranging from advanced graduate students and postdocs to the leaders in each field. Many more come for stays of a week or two, often to participate in one or more of the associated programmatic workshops (see below). Normally, the Institute runs two such programs simultaneously (a total of 70 to 90 long-term visitors in residence at a time), often with the goal of fostering interactions between the two.

Here are the programs carried out during the 5-year period of this grant, each program title being followed by a list of the members of its organizing committee. Much more detail on these programs, including synopses, schedules, and participant lists can be found on our web site and in the annual reports.

- Fall 2005: Nonlinear Dispersive Equations *Carlos Kenig, Sergiu Klainerman, Christophe Sogge, Gigliola Staffilani, Daniel Tataru*
- Fall 2005: Nonlinear Elliptic Equations and Its Applications *Xavier Cabré, Luis Caffarelli, L. Craig Evans, Cristian Gutiérrez, Lihe Wang, Paul Yang*
- Spring 2006: New Topological Structures in Physics *Mina Aganagic, Ralph Cohen, Petr Horava, Albrecht Klemm, Jack Morava, Hiraku Nakajima, Yongbin Ruan*
- Spring 2006: Rational and Integral Points on Higher-Dimensional Varieties *Fedor Bogomolov, Jean-Louis Colliot-Thélène, Bjorn Poonen, Alice Silverberg, Yuri Tschinkel*
- Fall 2006: Computational Applications of Algebraic Topology *Gunnar Carlsson, Persi Diaconis, Susan Holmes, Rick Jardine, Günter Ziegler*
- Fall 2006 and Spring 2007: Geometric Evolution Equations and Related Topics *Bennett Chow, Panagiota Daskalopoulos, Gerhardt Huisken, Peter Li, Lei Ni, Gang Tian*
- Spring 2007: Dynamical Systems *Christopher Jones, Jonathan Mattingly, Igor Mezic, Andrew Stuart, Lai-Sang Young*
- Fall 2007: Geometric Group Theory *Mladen Bestvina, Jon McCammond, Michah Sageev, Karen Vogtmann*
- Fall 2007: Teichmüller Theory and Kleinian Groups *Jeffrey Brock, Richard Canary, Howard Masur, Maryam Mirzakhani, Alan Reid*
- Spring 2008: Combinatorial Representation Theory *Persi Diaconis, Alexander Kleshchev, Bernard Leclerc, Peter Littelmann, Arun Ram, Ann Schilling, Richard Stanley*

[1] defined as '30 days or more'

- Spring 2008: Representation Theory of finite Groups and Related Topics *John Alperin, Michel Broué, John Carlson, Alexander Kleshchev, Jeremy Rickard, Bama Srinivasan*
- Fall 2008: Analysis on Singular Spaces *Gilles Carron, Eugenie Hunsicker, Richard Melrose, Michael Taylor, Jared Wunsch*
- Fall 2008: Ergodic Theory and Additive Combinatorics *Ben Green, Bryna Kra, Emmanuel Lesigne, Anthony Quas, Mate Wierdl*
- Spring 2009: Algebraic Geometry *William Fulton, Joe Harris, Brendan Hassett, János Kollár, Sándor Kovács, Robert Lazarsfeld, Ravi Vakil*
- Fall 2009: Tropical Geometry *Eva-Maria Feichtner, Ilia Itenberg, Grigory Mikhalkin, Bernd Sturmfels*
- Fall 2009 and Spring 2010: Symplectic and Contact Geometry and Topology *Yakov Eliashberg, John Etnyre, Eleny-Nicoleta Ionel, Dusa McDuff, Paul Seidel*
- Spring 2010: Homology Theories of Knots and Links *Mikhail Khovanov, Dusa McDuff, Peter Ozsváth, Lev Rozansky, Peter Teichner, Dylan Thurston, Zoltan Szabó*

Over the 5-year period of the grant, a total of 1205 members were in residence at MSRI for periods ranging from a month up to 10 months, which means an average of 240 members per year. The average length of stay was 73 days (approximately 2.4 months). Members were roughly evenly divided among 5-year cohorts, delineated by their year-from-PhD, with 45% of them having completed a PhD within the last 10 years of their visits to MSRI. Among the members, 57% were from US institutions and 47% were US citizen or US permanent residents, which is essentially in line with the composition of the graduate student population in the US for the last 10 years (about 45% of them have been Americans or Permanent Residents).

Women comprised roughly 19% of the members. While complete information on ethnicity is not available, two Native Americans, eight African-Americans, and thirty Latinos/Latinas stated their ethnic backgrounds.

We survey all of the program participants on exit and at intervals thereafter. These surveys are available upon request; there is no space to include a range of samples here. We will just give one quote: Alan W. Reid wrote, "As an organizer of the Teichmuller theory and Kleinian groups program who could not be in residence for the whole semester, I was able to stand back and look from the outside. My impression is that the program has been a fantastic success. This is in part because of the timeliness of the program. However, the key components were the well-balanced mix of young postdocs, senior people and the visitors. Many new collaborations have started, many old ones have been given impetus, and the feeling I get is of a subject that continues to produce excellent young people doing first-rate mathematics. The two drawbacks for me were that I couldn't come for the whole semester and, perhaps more importantly, I really feel one semester is too short of a time for such a program."

Workshops

During the period of this grant, MSRI has hosted around 30 workshops per year, a few of which are held off-site. We classify them into *programmatic* (i.e., those related to currently running programs), *non-programmatic*, and *summer graduate schools.* The non-programmatic workshops are further classified as 'hot topics', outreach, educational, interdisciplinary, or other.

Year of PhD	Number
2008–2009	654
2007	97
2002–2006	314
1997–2001	163
1992–1996	126
1987–1991	102
1982–1986	86
< 1982	266
Unknown	231
Non PhD	8
Totals	2047

The table at the left gives PhD 'age' data for the workshop participants in the year 2007–8, a representative year. The number of future PhDs is largely due to graduate students at workshops.

The format of individual workshops is variable. For a 5-day programmatic conference for example, there are typically around 20–25 research talks and/or panel discussions. Each talk is videorecorded and (within a couple of weeks) made available on MSRI's VMath web site, along with the lecturer's slides and/or the notes of a designated notetaker. The number of attendees is variable and is limited by our seating capacity, which is about 170 persons. This limit has occasionally been reached and exceeded, but a more typical attendance is around 120 persons.

The workshops in a given year break down as follows: There are usually 12 programmatic (four each of Connections for Women, Introductory, and Topical), about 5–10 non-programmatic (1–2 hot topics, 1–2 outreach, 1–3 educational, 1–2 interdisciplinary, and a few other), and about 4–6 summer graduate schools. The NSF funds all of these except for a few of the non-programmatic ones. We also leverage the NSF core support with supplemental funds from the NSA, divisions outside of DMS but still within the NSF, and private foundations. For example, over the past 5 years we have budgeted $20–25K of core NSF funds for each of the 5-day programmatic workshops and also ask the NSA to supplement those amounts for workshops whose topics are within their area of interest. Connections for Women workshops (which are typically 2 days and are held in conjunction with the introductory programmatic workshops) are funded at about $8–10K each.

There have been more workshops funded by DMS-0441170 than can be listed individually here. The complete listing of those can be obtained from the yearly reports.

Postdoctoral Fellows

In the 5-academic-year period 2005–10, MSRI has had 147 postdoctoral fellows (PDFs) in its scientific programs, of which 43 were female (making 29% of the total) and 11 identified themselves as members of under-represented minorities (making 7.5% of the total).

Of these, 98 (67%) came from US institutions. Breaking the data on these individuals down into source classified according to the AMS groupings of US institutions yields the following table, in which the columns tell where the PDFs went after their fellowships ended. For example, of the 45 PDFs that were at Group I Private institutions prior to arriving at MSRI, 31 went back to Group I Private institutions, 7 went to Group I Public institutions, 5 went to foreign instituions and the other two went to Group II and M.

Home Institution	Group I Private	Group I Public	Group II	Group III	Group M	Totals
Group I private	31	7	1	1	0	40
Group I public	7	16	0	0	0	23
Group II	1	5	8	0	0	14
Group III	0	1	0	0	0	1
Group M	1	6	0	0	1	8
Foreign	5	6	1	0	0	12
Totals	45	41	10	1	1	98

In exit surveys (and the 2-year-after surveys that we have from the years 2005–6, 2007–8, and 2009–10), the postdoctoral fellows uniformly report strongly positive experiences. They typically place the highest value on the opportunity to work with mentors and collaborators that they met during their time here, followed closely by their participation in the workshops.

Publications and Streaming Video

Our main publishing activity is in the *MSRI Publications Series.* During the years of the current grant, we have produced 6 volumes, with a few more in various stages of production.

Volume	Year	Title
52	2005	Combinatorial and Computational Geometry
53	2007	Assessing Mathematical Proficiency
54	2007	Dynamics, Ergodic Theory, and Geometry
55	2008	Probability, geometry, and integrable systems
56	2009	Games of No Chance 3
57	2010	A Window into Zeta and Modular Physics

In addition, we have published and distributed, essentially twice yearly, the MSRI newsletter *The Emissary* as well as occasional booklets, such as *The Mathematics of Climate Change* and *Teaching Teachers Mathematics.*

Since all of our workshop lectures are recorded, converted into streaming video, and made available for viewing or download on our VMath, we now have a rather large collection. For example, in Fall 2005 alone, we recorded 118 hour-long lectures, covering essentially every lecture in every one of the workshops that fall. This was a typical semester, so that more than 1000 of MSRI lectures from the period 2005–10 are available from the VMath site.

The rest of this document contains the detailed report of the activities held during the last year, 2009-2010, of grant #0441170.

1. Overview of Activities

This annual report covers MSRI projects and activities that occurred during the fifth year and last year of the NSF core grant DMS–0441170.

1.1 New Developments

It has been an eventful year at MSRI. Not only have the programs *Tropical Geometry* (TG), *Contact and Symplectic Geometry and Topology* (SCGT), and *Homology Theories of Knots and Links* (HTKL) been popular and their workshops heavily attended, but we have had a number of exciting additional workshops, such as the September's (2009) *Black Holes in Relativity*. This was MSRI's annual Hot Topics workshop, focusing on what are known as trapped surfaces. The latest breakthrough (as of September 2009) in understanding the formation of such surfaces came from the recently made available 600–page monograph *"The Formation of Black Holes in General Relativity"* by Christodoulou. A major coup was achieved in securing his presence as the main speaker for this workshop. Christodoulou gave five highly detailed and comprehensive lectures explaining the philosophy, technical constructions, and conclusions of his main result that trapped surfaces form in evolution for the Einstein vacuum equations from completely dispersed initial configurations, a phenomenon caused purely by the focusing of gravitational waves. The success of this workshop, especially for junior researchers such as postdocs and graduate students, is eloquently described in its final report, which can be found in the Appendix.

All programs had stellar researchers. Three (3) of them, Clifford Taubes, Peter Ozsvath, and Tomasz Mrowka, were generously funded by the Clay Mathematics Institute via their Clay Senior Awards. Taubes had just received (2008) the National Academy of Sciences Mathematics Award and shared (2009) the Shaw Prize with Simon Donaldson, while Ozsvath and Mrowka (2007) had received the Veblen Prize. Another ten (10) researchers, Alicia Dickenstein, Andreas Gathman, Emmanuel Giroux, Mark Gross, Ko Honda, Mikhail Khovanov, Dusa McDuff, Grigory Mikhalkin, Leonid Polterovich, and Catharina Stroppel, were funded by MSRI's Eisenbud Endowment and by a grant from the Simons Foundation.

The programs had been thoughtfully paired to maximize cross fertilization among disciplines. The overlap extended back into the planning stages when organizers of parallel programs discussed postdoc applications and awarded joint postdoctoral fellowships. For example, David Shea, Vela Vick, and Vera Vertesi were postdocs that belong to both the SCGT and the HTKL programs. Brett Parker was a postdoc in the TG program as well as in the SCGT one. In addition, several of the senior researchers were members of two programs. Some notable examples were Ko Honda, Dusa McDuff, and Clifford Taubes.

More importantly, due to this exceptional interaction among researchers from different programs, striking results were obtained. Such are the deep connections established between sutured Heegaard-Floer theory (HTKL program) and contact geometry (SCGT program). The beautiful work of Colin, Ghiggini, Honda, and, independently, of Kutluhan, Lee, and Taubes proved that the long-conjectured equivalence of Seiberg-Witten Floer Homology and Heegaard-Floer Homology is indeed valid. Another example of a breakthrough obtained due to interactions between the TG and SCGT researchers is that of Abouzaid, Gross, and Siebert, which establishes the relation between tropical curves and the Fukaya-Oh degenerations of Lagrangian disks with the resulting tropical Fukaya category. Section 1.3 and the Appendix contain the detailed reports of all of our scientific programs and workshops, including a plethora of exciting discoveries and results.

Postdoctoral Program. In the spring of 2009, the impact of the economic downturn hit academia hard, causing hiring freezes and cancelled job searches. For mathematics, this represented a loss of some 400 positions for recent PhDs. The National Science Foundation, through its seven mathematics institutes (including MSRI), responded by creating new postdoctoral fellowships. This partnership resulted in the creation of 45 postdoctoral positions for young, highly-trained mathematical scientists from across the country. MSRI awarded ten of these fellowships. Of those exceptional mathematicians, four, Tristam Bogart, Chris Hillar, Eric Katz, and Sikimeti Mau, participated in MSRI programs during the academic year of 2009–10 and continued on to their mentor's institution where they will be supported for another year. Another six received one- and two-year fellowships allowing them to pursue their work at several institutions: Vigleik Angeltveit is working with Peter May at the University of Chicago and will continue to do so next year; Scott Crofts is at UC Santa Cruz for two years to work with Martin Weissman; Anton Dochtermann was awarded a one–year (2010-11), fellowship to work with Gunnar Carlsson at Stanford University; Karl Mahlburg is at Princeton University working with Manjul Bhargava and Peter Sarnak (2009–11); Abraham Smith was awarded a 2-year fellowship at McGill University to work with Niky Karman; and Jared Speck will be working (2010–11) at Princeton University, with Sergiu Klainerman.
See details at http://www.msri.org/specials/nsfpostdocs, in Chapter 3, and in the Appendix.

Summer Graduate Schools. During the summer of 2009, MSRI funded 168 graduate students to attend Summer Graduate workshops. Two were held at MSRI, and the others were held at the University of Washington, Seattle; the National Center for Atmospheric Research, Boulder; the University of Victoria; and the Park City Mathematics Institute. For most of the summer graduate workshops, enrollment is based on a first-come first-serve policy. The workshops are so popular that some (very dedicated) graduate chairs wait until 12:01am of the first open enrollment day to nominate their students. Detailed descriptions and reports for each of the SGS can be found starting in Section 4.1 and in the Appendix.

MSRI-UP program. This undergraduate research program is targeted at underrepresented minorities with the goal of increasing their interest and enrollment in mathematics graduate programs. In the summer of 2010 the lead director was Duane Cooper and the primary instructor was Professor Edray Goins. The subject was Elliptic Curves and Applications. It is fair to say that over the years this program has drawn national praise for its scientific and mentoring excellence. Two students from the 2007 MSRI UP summer program, Talea Layo and Gina Pomann, have received 2010 NSF graduate research fellowships. A detailed report can be found in Chapter 5 and in the Appendix. In addition, Ivelisse Rubio, (one of the 5 directors of MSRI UP) won the Dr. Etta Z. Falconer Award for Mentoring and Commitment to Diversity. This award recognizes individuals who have demonstrated a professional commitment to mentoring and increasing diversity in the sciences, in particular, the mathematical sciences.

K–12 Mathematics Education: What Can Math Departments Do? Math departments have both an opportunity and an obligation to help improve elementary and secondary mathematics education. That was the consensus of leaders in mathematics education during the panel discussion at MSRI's Committee of Academic Sponsors meeting in March 2010. Aspiring teachers need to develop a deep, flexible, and intuitive understanding of basic mathematics, they need to learn how to think mathematically, and they need to be exposed to the beauty and delight of mathematics. Mathematicians have a responsibility, both to their own profession and to the nation, to help teachers these develop. One of the most striking moments of this meeting was Deborah Ball's talk. She started with a very simple slide depicting three multiplications done by young children. Dr. Ball boldly challenged her audience, math department chairs and researchers, to explain what mathematical steps could have produced these three (wrong) answers. While some researchers provided plausible guesses for two of the multiplications, no one in the audience could come up with an explanation for the third one. It was a brilliant illustration that teaching elementary mathematics can still be mathematically (and, as Ball mentioned, creatively) challenging and stimulating. Many of us still wonder about the thought process of this child!

National Association of Mathematical Circles (NAMC). The NAMC was created in 2009 by MSRI to provide support for national and international Math Circles and similar programs with the goal that extra-curricular mathematical activities should become as common as sports or music. Some circles (such as the Berkeley Math Circle, BMC) are aimed at students who already excel at mathematics, while other circles (such as San Francisco Math Circle, SFMC) are aimed at recruiting new students into mathematics. Still other math circles are aimed at teachers (e.g. the Bay Area Circle for Teachers, BACT). Math circles also interact with other extracurricular mathematics programs, such as mathematics festivals (e.g. the Julia Robinson Mathematics Festivals), math contests (e.g. Bay Area Math Olympiad), and summer math programs. A web page for the NAMC, http://mathcircles.org, was unveiled at the MAA MathFest in Portland, Oregon, in August of 2009. This web page is being developed with the generous support from the Akamai Foundation. The NAMC was one of the sponsors of the MathFest and partnered with the Special interest group of the Mathematical Association of America on Math Circles for Students and Teachers (SIGMAA MCST), and in January 2010, the NAMC had a booth at the Joint Mathematics Meetings in San Francisco. As a result of these efforts, there are now more than 80 math circles registered with the NAMC in the United States. The NAMC hosted its first national meeting, Circle on the Road, from March 13 to March 15, 2010 in Tempe, Arizona. This town was chosen as the site of the first meeting because Phoenix is a large, diverse metropolitan area with no math circle program. On Saturday, March 13, over 300 students, parents, and teachers flooded Arizona State University's recently established School of Mathematical and Statistical Sciences. Hands-on activities immediately captured the attention of participants of all ages. Assisted by experienced graduate students and research faculty, the visitors quickly transitioned from simply playing fun games to raising and exploring mathematical questions. Led by some of the best mathematics communicators in the nation, students explored topics such as solving cubic equations, decrypting secret messages, and exploring tangled ropes using number theory. Everyone agreed the meeting was an enormous success for all parties involved, including one particularly inspiring student who came 300 miles for the pleasure of doing mathematics.

Mexican Mathematical Society. In June 2010, MSRI was delighted to host the opening ceremony of the triennial Joint Meeting of the American Mathematical Society and the Mexican Mathematical Society. It was a great pleasure to host our neighbors to the south as we continue to reach out to mathematicians, both at home and abroad, in MSRI's continuing mission to serve the mathematics community and our society.

Public Understanding of Mathematics. Beyond its scientific programs, MSRI is involved in many more activities and modes of serving the mathematics community. MSRI has taken a leading role in continuing the dialog between mathematics educators and mathematical researchers regarding outreach to minority and underserved communities (at all levels, beginning with K-12 mathematics education) and the sponsorship of cultural events that explore the roles of mathematics in our society and the lives of those involved in math.

Gioia de Cari's Truth Values: One Girl's Romp through MIT's Male Math Maze. At the 2010 Joint Mathematics Meetings in San Francisco, MSRI sponsored a production of this one-woman play, which was a hit in Boston and New York. It turned out to be a great success with the JMM attendees, as was the post-performance discussion; the two scheduled performances were sold out and a third one was added. MSRI donated the profits of this event to the Association for Women in Mathematics.

SF Playground, "To Knot or not to Knot". MSRI's collaboration continues with SF Playground, a local theater company and playwrights pool, by sponsoring an annual competition for short plays on a mathematical theme. This year, having so many knot theorists around, we chose the theme ``To Knot or not to Knot''. A lively evening ensued when the writers met the mathematicians and heard them describe their work. The best six submissions were performed at the Berkeley Repertory Theatre and set an attendance record for a Playground event!

Logicomix: An Epic Search for Truth. A third cultural event that MSRI sponsored, in March 2010, was a discussion of the 2009 graphic novel Logicomix: An Epic Search for Truth, by Apostolos Doxiadis and Christos Papadimitriou. This novel follows the personal and professional life of Bertrand Russell in his quest to place mathematics on a firm logical foundation. The community response to these events shows that a meaningful dialog about mathematics with nonmathematicians is a fruitful and important task for our community and one in which MSRI remains fully engaged.

Chicago Mercantile Exchange. We continue to co-sponsor, with the Chicago Mercantile Exchange, the CME Group-MSRI Prize for innovation in financial mathematics and economics. The fourth award of the prize took place in Chicago in September 2009, and one of MSRI's newest trustees, Sanford Grossman, was the recipient.

iPhones and iPads concert. For a couple of hours on May 7, members' and visitors' iPhones and iPads became musical instruments in MSRI's Simons Auditorium, under the baton of Stanford's "computer musicians" Ge Wang and Jieun Oh. Audience members brought their mobile gadgets and enjoyed an interactive iPhone/iPad music class that was unlike any other event in MSRI's Music and Mathematics series. Ge Wang, an Assistant Professor at Stanford's Center for Computer Research in Music and Acoustics (CCRMA), is the founder and director of SLOrk, the Stanford Laptop Orchestra, and MoPhO, the Stanford Mobile Phone Orchestra http://mopho.stanford.edu. Graduate student and virtuoso flute player Jieun Oh codirects the two orchestras. A second part of the program, following a reception, featured a lecture and demonstration of Ocarina for the iPhone and Magic Piano for the iPad, played by Wang with Oh. They were joined by MSRI's Director Robert Bryant and UC Berkeley Professor David Eisenbud for a discussion about state-of-the-art technologies in music-making. Ge Wang's research focuses on interactive software systems for computers (http://ccrma.stanford.edu/~ge).

1.2 Summary of Demographic Data for 2009-10 Activities

During the academic year 2009–10, MSRI hosted 31 NSF Postdoctoral Fellows, 225 program members (members that came for a period of at least one month), and 1716 workshop participants.

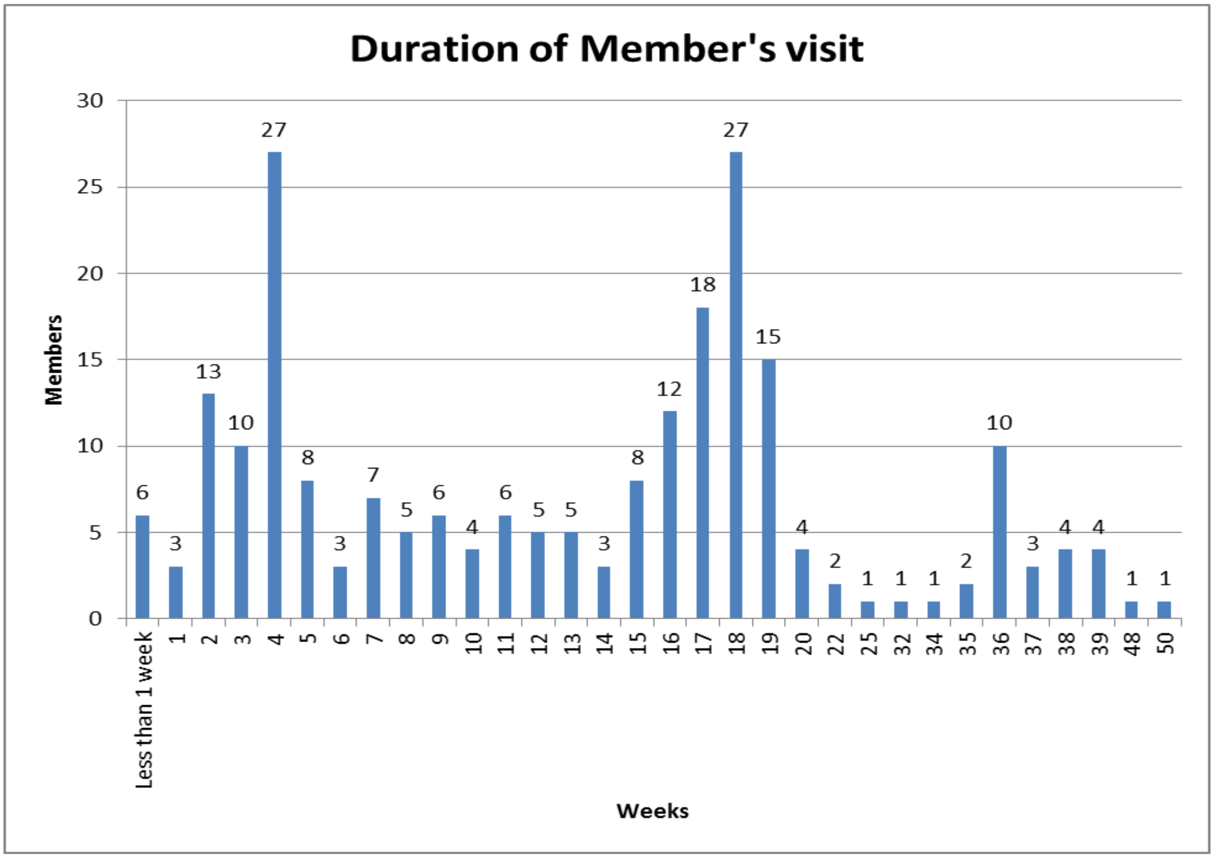
The Postdoctoral program was particularly successful and is described in detail in Chapters 2 and 3. Of the Fellows, 22% were female, 45% were U.S. Citizens or Permanent Residents, and 58% listed a U.S. university as home institution. Of those institutions, 33% are located in the Northeast, 33% in the West, 17% in the Midwest, and the remaining 17% in the South. Detailed demographic tables can be found in Chapter 3. Of the 31 postdocs, 15 (48%) were from group I institutions, 11 (35%) were from foreign universities, and the remainder 5 (17%) were from U.S. institutions belonging to group II, III, and M.

MSRI had a total of 225 long-term members. Member spent an average of 85 days at MSRI, with peak attendance in October for the fall semester and March for the spring semester. Of the members, 49 (22%) were female and 5 belonged to the Hispanic/Latino community. Of the members, 113 (50%) reported being U.S. Citizens or Permanent Residents and 129 (57%) listed a U.S. university as home institution. Of those institutions, 16% are located in the Midwest, 33% in the West, 38% in the Northeast, and 13% in the South. Of the members, 65% had received a Ph.D degree on or after 1999, 21% received one between 1989 and 1998, and the remaining 14% had received a Ph.D. on or prior to 1988. Detailed demographic data can be found in Chapter 2.

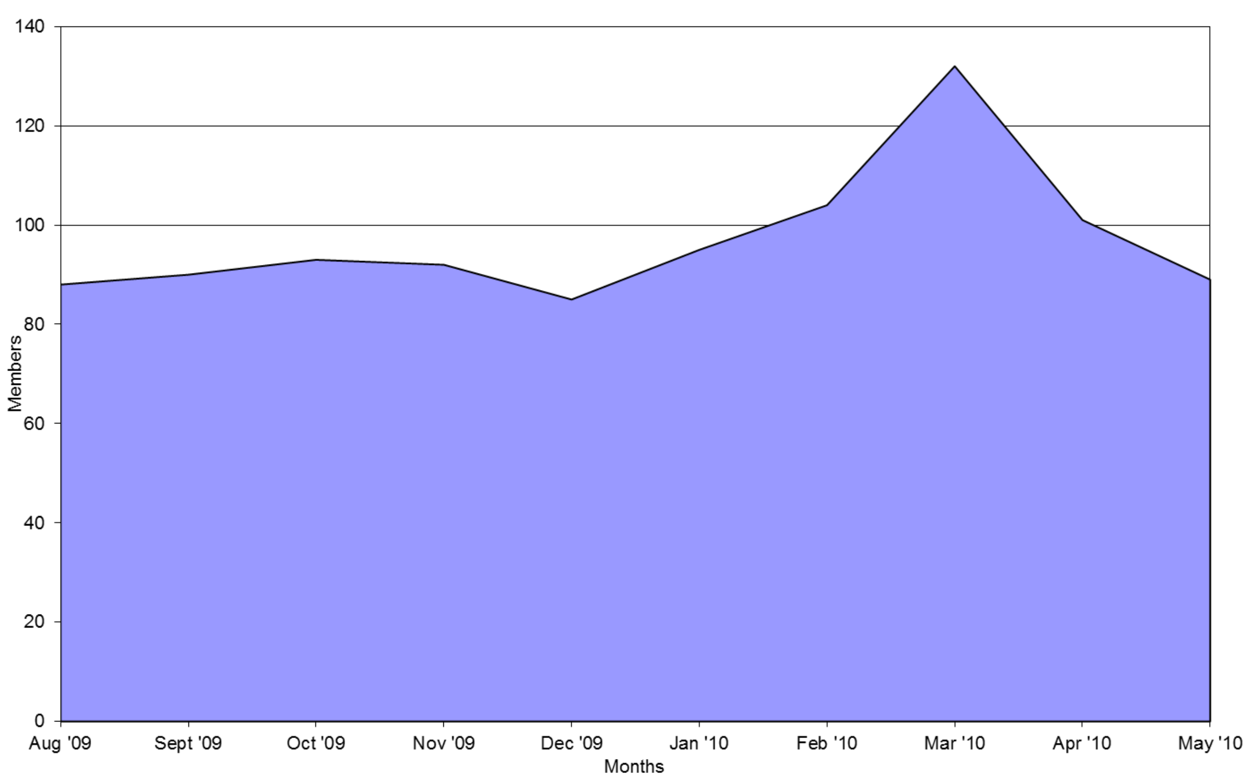
In the 2009–10 workshops, MSRI hosted 1716 separate visits (some visitors attended multiple events). MSRI obtained data from 1681 (98%) participants. Of the 1681 participants, 561 (33%) were female and 792 (53%) were U.S. Citizens or Permanent Residents, of which 68 (8%) reported being a member of an under-represented minority. In addition, 69% of the 1681 participants came from a U.S. institution. The U.S. regional distribution of the participants' home institution was 16 % from the Midwest, 43% from the West, 26% from the Northeast, and the remaining 15% from the South. Demographic data on workshop participant can be found in Chapters 2 and 4.

Length of Stay Summary

All program members	Fall 2009	Spring 2010	2009-10	2004-10
Total Member Days	10201	12149	22350	98603
Total # of Members (non-distinct)	117	147	264	1362
Average # of Days per Member	87.19	82.65	84.66	72.40
Average # of Months per Member	2.9	2.8	2.8	2.4
All female program members	**Fall 2009**	**Spring 2010**	**2009-10**	
Total Female Member Days	2328	2538	4866	
Total # of Female Members (non-distinct)	28	32	60	
Average # of Days per Female Member	83.14	79.31	81.10	
Average # of Months per Female Member	2.8	2.6	2.7	



2009-2010 Members at MSRI by Month



1.3 Scientific Programs and their Associated Workshops

There were 3 major and 2 smaller programs for the MSRI fiscal year 2009–10, and 13 workshops were associated with them.
Note: In the lists of organizers of each activity, an asterisk (*) denotes lead organizer(s).

Program 1: Symplectic and Contact Geometry and Topology (SCGT)
August 17, 2009 to May 21, 2010
Organized by: Yakov Eliashberg (Stanford University), John Etnyre (Georgia Institute of Technology), Eleny-Nicoleta Ionel (Stanford University), Dusa McDuff (Barnard College, Columbia University), and Paul Seidel (Massachusetts Institute of Technology)*

In the slightly more than two decades that have elapsed since the fields of Symplectic and Contact Topology were created, the field has grown enormously, and unforeseen new connections within Mathematics and Physics have been found. The goals of the program at MSRI were to

- promote the cross-pollination of ideas between different areas of symplectic and contact geometry,
- help assess and formulate the main outstanding fundamental problems and directions in the field,
- lead to new breakthroughs and solutions of some of the main problems in the area;
- discover new applications of symplectic and contact geometry in mathematics and physics, and
- educate a new generation of young mathematicians, giving them a broader view of the subject and the capability to employ techniques from different areas in their research.

To achieve these goals, the program concentrated on three broad, interrelated themes that encompass many of the modern trends in symplectic geometry: algebraic structures associated with holomorphic curves, symplectic and contact geometry in low dimensional topology, and symplectic topology and dynamics.

Workshops associated with the SCGT Program:

Workshop 1: Connections for Women: Symplectic and Contact Geometry and Topology
August 14, 2009 to August 15, 2009
Organized by Eleny-Nicoleta Ionel (Stanford University) and Dusa McDuff (Barnard College, Columbia University)*

The goal of this workshop was to establish a bridge between the graduate student workshop that ended on August 14, 2009 and the Introductory Workshop that began August 17, 2009. After some elementary talks describing some of the main questions in the field, there was an extended discussion session intended to explain basic concepts to those unfamiliar with the area. It was also an opportunity for young researchers in the field to present their work. To facilitate networking among women and members of underrepresented minorities, MSRI hosted a dinner at a nearby restaurant on Friday evening.

Workshop 2: Introductory Workshop: Symplectic and Contact Geometry and Topology
August 17, 2009 to August 21, 2009

Organized by John Etnyre (Georgia Institute of Technology), Dusa McDuff (Barnard College, Columbia University), and Lisa Traynor (Bryn Mawr)*

The aims of this workshop were to introduce people to a broad swath of the field and to frame its most important problems. Each day was organized around a basic topic, such as how to count holomorphic curves with boundary on a Lagrangian submanifold (which leads to various versions of Floer theory) or how to understand the general structure of symplectic and contact manifolds. There was also an introduction to the analytic and algebraic aspects of symplectic field theory and a discussion of some applications.

Workshop 3: Algebraic Structures in the Theory of Holomorphic Curves
November 16, 2009 to November 20, 2009
Organized by Mohammed Abouzaid (Clay Mathematics Institute), Yakov Eliashberg (Stanford University), Kenji Fukaya (Kyoto University), Eleny-Nicoleta Ionel (Stanford University), Lenny Ng (Duke University), and Paul Seidel (MIT)*

The theory of holomorphic curves in symplectic manifolds leads to rich algebraic structures. The study of these structures is increasingly important both for understanding the theory itself, and for actual computations and applications. The aim of the workshop was to survey ongoing developments in the area. Some of the topics of interest were

- cohomological field theories,
- relative and tropical Gromov-Witten invariants,
- Symplectic Field Theory (SFT) and connections with string topology, and
- theories of holomorphic curves with Lagrangian boundary conditions, such as relative SFT, open Gromov-Witten theory, and Fukaya categories.

Workshop 4: Symplectic and Contact Topology and Dynamics: Puzzles and Horizons
March 22, 2010 to March 26, 2010
Organized by Paul Biran (Tel Aviv University), John Etnyre (Georgia Institute of Technology), Helmut Hofer (Courant Institute), Dusa McDuff (Barnard College), and Leonid Polterovich (Tel Aviv University)*

This workshop focused on recent progress in central problems in symplectic and contact topology and Hamiltonian dynamics, such as rigidity of Lagrangian submanifolds, algebra/topology/geometry of symplectomorphism and contactomorphism groups, exotic symplectic and contact structures, and existence of periodic orbits of Hamiltonian systems and Reeb flows. It explained applications of the 'large machines', such as Floer Theory, Symplectic Field Theory, and Fukaya categories, demonstrating where these machines do not yet provide satisfactory answers. Special attention was also paid to articulating new problems and directions, as well as to explaining interactions between symplectic and contact topology and other fields.

Workshop 5: Symplectic and Poisson Geometry in interaction with Algebra, Analysis and Topology
May 04, 2010 to May 07, 2010
Organized by Yakov Eliashberg (Stanford University), Alvaro Pelayo (University of California, Berkeley), Steve Zelditch (Northwestern University), and Maciej Zworski (University of California, Berkeley)*

The first week of May 2010 coincided with the first anniversary of Alan Weinstein's retirement from UC Berkeley. Weinstein has been one of the most influential figures in symplectic geometry, Poisson geometry, and analysis in the past forty years. Weinstein's fundamental work inspired many researchers and led to the development of central concepts in symplectic and Poisson geometry and to the establishment of symplectic geometry as an independent discipline within mathematics. This conference was a forum to celebrate Weinstein's fundamental contributions to geometry and mathematics at large.

Workshop 6: Symplectic Geometry, Noncommutative Geometry and Physics
***** Sponsor: Hayashibara Foundation**
May 10, 2010 to May 14, 2010
Organized by Robbert Dijkgraaf (University of Amsterdam), Tohru Eguchi (Kyoto University), Yakov Eliashberg (Stanford University), Kenji Fukaya (Kyoto University), Yoshiaki Maeda (Keio University), Dusa McDuff (Barnard College, Columbia University), Paul Seidel (Massachusetts Institute of Technology), and Alan Weinstein (University of California, Berkeley)*

Symplectic geometry originated as a mathematical language for Hamiltonian mechanics, but during the last three decades, it has witnessed both spectacular development of the mathematical theory and discovery of new connections and applications to Physics. Meanwhile, non-commutative geometry naturally entered into this picture.

The workshop aimed to highlight some of these connections and further boost interactions between mathematicians and physicists working in related areas. It consisted of 4 mini-courses given by Denis Auroux, Robbert Dijkgraaf, Yan Soibelman, and Katrin Wehrheim, as well as lectures given by physicists and mathematicians, such as Manabu Akaho, Michel Van den Bergh, Tohru Eguchi, Bertrand Eynard, Hiroshige Kajiura, Anton Kapustin, Yong-Geun Oh, Hiroshi Ooguri, Yongbin Ruan, Dennis Sullivan, Dmitry Tamarkin, and Bruno Vallet.

SCGT Program Highlights

The year-long program ran in parallel with two tightly related semester-long programs: Tropical Geometry in the Fall and Homology Theories for Knots and Links in the Spring. All three fields have close connections, and the resulting interaction with the parallel programs was one of the keys to the success of the SCGT program. The overlap extended back into the planning stages when the organizers discussed postdoc applications with the organizers of the parallel programs, resulting in several postdocs participating in more than one programs.

A prime example of the interaction between the programs was the *Sutured Manifolds and the Contact Category* informal working group, where deep connections between sutured Heegaard-Floer theory (represented by the HTKL program) and contact geometry (represented by the SCGT program) were explored. It was the first extended exposition of a theory that is still in development.

Another example and a major success of the SCGT program (in interaction with the program on Homology Theories for Knots and Links) was establishing the equivalence of three different homology theories: the Seiberg-Witten homology theory constructed by Kronheimer and Mrowka, the Heegaard homology theory of Ozsvath and Szabo, and the Embedded Contact

Homology Theory of Hutchings and Taubes. This shows that three very different ways of constructing three- and four-dimensional manifold invariants, based on solving quite different kinds of PDEs ultimately yield the same information. The proofs, by Kutluhan–Lee–Taubes and Colin–Ghiggini–Honda, are both very concrete and geometric but quite different in flavor. These results already have a lot of remarkable consequences and will undoubtedly bring many more exciting new developments.

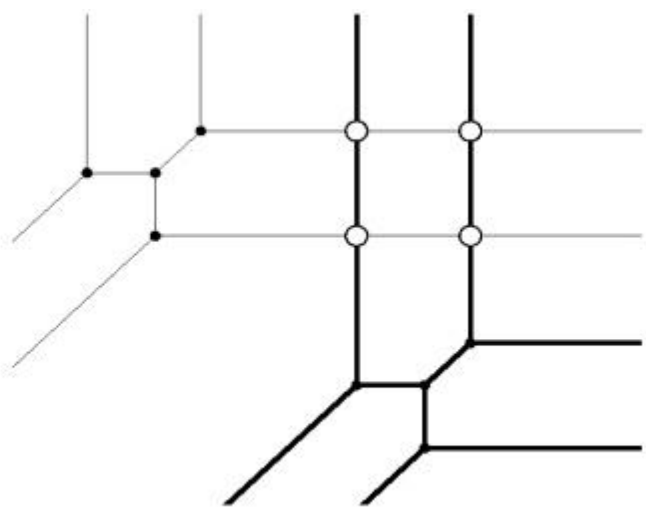
The Broken Dreams Seminar was an informal seminar run during the Fall semester only. In these seminars, the speaker discussed ideas that were conceptually exciting yet, in practice, did not quite work out. This was not a seminar where one talks about a theorem proved but rather about results that might be true and that the speaker tried to prove. Though there were only four talks in this seminar (by Cielieback, Taubes, Montgomery, and Cornea), they were highly successful and popular.

In the words of one program participant, there was "too much exciting stuff going on" at any time. This attests both to the general healthy state of developments in the area and to the strong positive effect of the MSRI program.

Program 2: Tropical Geometry (TG)

August 17, 2009 to December 18, 2009

Organized by Eva-Maria Feichtner (University of Bremen), Ilia Itenberg (Université de Strasbourg), Grigory Mikhalkin (Université de Genève), and Bernd Sturmfels (University of California, Berkeley)*



Bézout's Theroem: two tropical conics intersect in four points.*

Tropical Geometry is algebraic geometry over the min-plus algebra. It is a young subject that in recent years has both established itself as an area in its own right and unveiled its deep connections to numerous branches of pure and applied mathematics. From an algebro-geometric point of view, algebraic varieties over a field with non-archimedean valuation are replaced by polyhedral complexes, nevertheless retaining much of the information about the original varieties. From the point of view of complex geometry, the geometric combinatorial structure of tropical varieties is a maximal degeneration of a complex structure on a manifold.[1]

The tropical transition from objects of algebraic geometry to the polyhedral realm is an extension of the classical theory of toric varieties. It opens up problems about algebraic varieties to a completely new set of techniques and has already led to remarkable results in Enumerative Algebraic Geometry, Dynamical Systems and Computational Algebra, among other fields, and to applications in Algebraic Statistics and Statistical Physics.

[1] Illustration from Jürgen Richter-Gebert, Bernd Sturmfels and Thorsten Theobald: First Steps in Tropical Geometry; in: Idempotent mathematics and mathematical physics, Contemp. Math. 377, AMS, 2005, pp. 289–317.

The goal of this program was, through its workshops and various other activities, to bring together researchers from the broad range of research areas involved and to provide an extended forum of interaction on Tropical Geometry while it is still in its formative phase.

Workshops associated with the Tropical Geometry Program:

Workshop 1: Connections for Women: Tropical Geometry
August 22, 2009 to August 23, 2009
Organized by Alicia Dickenstein (University of Buenos Aires) and Eva Maria Feichtner* (University of Bremen)*

The aim of this workshop was to introduce advanced graduate students and postdoctoral fellows to Tropical Geometry. Various aspects of this multi-faceted field were highlighted in two short courses, comprising lectures and exercise/discussion sessions as well as research talks. The workshop thus provided the participants with an excellent introduction to the forthcoming events of the program.

There were two short courses given by Hannah Markwig (University of Goettingen) and Federico Ardila (San Francisco State University).

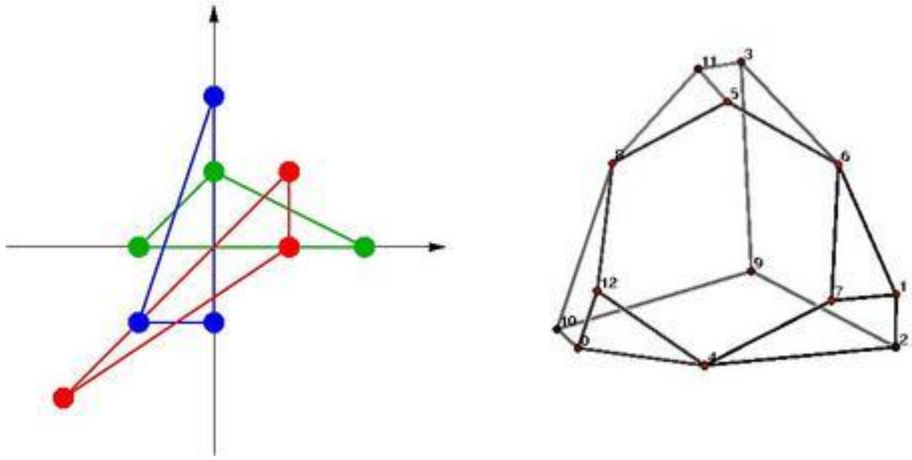
Additional research lectures were given by

Marianne Akian (Institut National de Recherche en Informatique et en Automatique, Saclay - Ile de France), Lucia Lopez de Medrano (Universidad Nacional Autonoma de Mexico), Annette Werner (University of Frankfurt), Lauren Williams (Harvard University, MSRI), and Josephine Yu (Massachusetts Institute of Technology, MSRI), among others.

The organizers planned for a session of very short contributions by participants, consisting of focused presentations of two to three slides each. This was an important activity of the workshop, so we encouraged participants of all levels to send an abstract to the organizers by email in addition to completing the registration.

The scientific research was complemented by a round-table discussion on the career development of female mathematicians. Panelists were: Hélène Barcelo (MSRI), Diane Maclagan (University of Warwick), Lauren Williams (University of California, Berkeley, and MSRI), Josephine Yu (Massachusetts Institute of Technology, and MSRI), and Angelica Cueto (University of California, Berkeley).

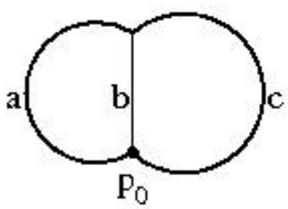
Organizers particularly encouraged female participants to attend this workshop and gave them priority for travel and lodging expenses.

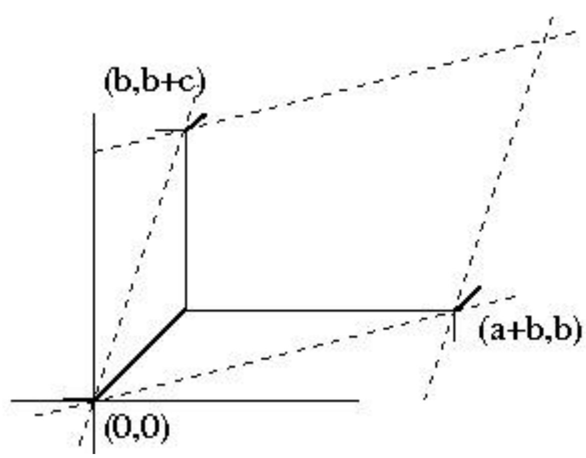


An illustration for tropical implicitization from B. Sturmfels and J. Yu: "Tropical implicitization and mixed fiber polytopes", in Software for Algebraic Geometry (editors M. Stillman, N. Takayama and J. Verschelde), I.M.A. Volumes in Mathematics and its Applications 148, Springer, New York, 2008, pp. 111–132.

Workshop 2: Introductory Workshop: Tropical Geometry
August 24, 2009 to August 28, 2009
Organized by Eva Maria Feichtner (University of Bremen), Ilia Itenberg (University of Strasbourg), Grigory Mikhalkin (Université de Genève), and Bernd Sturmfels (University of California, Berkeley)*

This workshop laid the foundations for the program that followed. Mini-courses comprising lectures and exercise/discussion sessions covered the foundational aspects of tropical geometry as well as its connections with adjacent areas: symplectic geometry, several complex variables, algebraic geometry (in particular, enumerative and computational aspects), and geometric combinatorics. The mini-courses were augmented by research talks on current tropical developments in order to open the scene and set up new goals in the beginning of the semester.





"An illustration of the tropical Abel-Jacobi map" from G. Milkhalkin, I. Zharkov: "Tropical curves, their Jacobians and Theta functions," arXiv: math/0612267.

Workshop 3: Tropical Geometry in Combinatorics and Algebra
October 12, 2009 to October 16, 2009
Organized by Federico Ardila (San Francisco State University), David Speyer (Massachusetts Institute of Technology), Jenia Tevelev (University of Massachusetts, Amherst), and Lauren Williams (University of California, Berkeley)*

This workshop concentrated on tropical methods in Combinatorics and Algebra. Some of the topics explored were

- tropical ideas in combinatorial linear algebra, such as tropical convexity, tropical linear spaces and oriented matroids, tropical matrix algebra and its applications;
- tropical methods in combinatorial representation theory, including both discovery of new formulas and improved understanding of old ones;
- computational issues, including both how to compute tropical objects and how to use tropical tools in other computational settings; and
- applications of tropical methods in algebraic statistics.

Workshop 4: Tropical Structures in Geometry and Physics
November 30, 2009 to December 04, 2009
Organized by Mark Gross (University of California, San Diego), Kentaro Hori (University of Toronto), Viatcheslav Kharlamov (Université de Strasbourg), and Richard Kenyon (Brown University)*

One of the successes of tropical geometry is its applications to a number of different areas of currently developing mathematics. Among these are enumerative geometry, symplectic field theory, mirror symmetry, dimer models/random surfaces, amoebas and algae, instantons, cluster varieties, and tropical compactifications. While these fields appear quite diverse, the common meeting ground of tropical geometry provided a basis for fruitful interactions between participants.

T G Program Highlights

The Tropical Geometry program at MSRI was the first major research program at a mathematics institute devoted entirely to the subject. The program was the culmination of a bout of activity in this newly emerging field and will likely be recognized as a milestone on the way to TG becoming a recognized discipline that straddles Algebra, Analysis, Combinatorics, and Geometry. The response to the program from the emerging tropical community was enthusiastic.

Six of eight research professors were in residence for the full duration of the program as were all of the four organizers. Together with 23 research members, most of them staying for several months, they shaped an exciting program and helped provide mentoring for the unusually high numbers of postdocs (16) and program associates (9). Special care was taken in assigning senior mentors to the postdocs, aiming to avoid the obvious matchings and to assign mentors who could introduce new aspects, topics, and contacts to the postdoc's work. The mentoring program received a wealth of positive feed-back and led to many new collaborations. Two out of eight research professors in the program were women, as were 5 out of 23 research members and 5 out of 16 postdocs.

Besides two introductory workshops and two topical workshops, a number of seminars and working groups took place throughout the program. Notably, the Tropical Colloquium and the Tropical Seminar provided opportunities for program participants to report on their latest progress. A weekly postdoc seminar that ran jointly with the SCGT program provided a forum for postdocs to talk about their work and interests. The postdoc seminar was followed by an MSRI-sponsored pizza lunch that provided ample opportunity for informal conversation and exchange.

A characteristic feature of the Tropical Geometry program was the strong and active participation of graduate students. This lively group was comprised of students from UC Berkeley and San Francisco State University, as well as students from other institutions who came to MSRI together with their doctoral advisors. In addition to a weekly graduate student seminar, there was a more informal 'What-Is' Seminar that offered a forum for graduate students and postdocs to interact and to learn about relevant mathematical concepts.

There was ample interaction with the SCGT program run in parallel at MSRI in the fall of 2009. This happened both on the informal level of conversations and collaborations and on a more formal level in the joint postdoc seminar, the mini-course by Denis Auroux (a member of the SCGT program) in the introductory workshop, and the postdoc position for Brett Parker shared by both programs. Another highly visible event was the bi-weekly MSRI Evans Lecture Series organized in collaboration with the SCGT program.

A particularly exciting development was the emerging connection between tropical geometry and number theory, which was highlighted by the work of Matt Baker, Vladimir Berkovich, Walter Gubler, and Sam Payne. This was enabled by Payne's remarkable result that Berkovich's analytification of an algebraic variety is the inverse limit of all tropical varieties obtained by choosing a concrete embedding. Walter Gubler solved the longstanding Bogomolov conjecture on equidistribution of points of bounded height on abelian varieties using tropical analytic geometry.

Program 3: Homology Theories of Knots and Links (HTKL)

January 11, 2010 to May 21, 2010

Organized by Mikhail Khovanov (Columbia University), Dusa McDuff (Barnard College, Columbia University), Peter Ozsváth (Columbia University), Lev Rozansky (University of North Carolina), Peter Teichner (University of California, Berkeley), Dylan Thurston (Barnard College, Columbia University), and Zoltan Szabó (Princeton University)*

The goals of this program were to

- promote communication with related disciplines, including the symplectic geometry program in 2009–10;

- lead to new breakthroughs in the subject and find new applications to low dimensional topology (knot theory, three-manifold topology, and smooth four- manifold topology); and
- educate a new generation of graduate students and PhD students in this exciting and rapidly-changing subject.

The program focused on algebraic link homology and Heegaard-Floer homology.

Khovanov's theory of links is a very young and rapidly -developing area drawing on many branches of mathematics. The subject has its roots in representation theory, and it has benefited from its interactions with low dimensional classical and quantum topology and symplectic geometry. In the short period since its birth, link homology has already exhibited the remarkable feature of fusing together many distinct areas of mathematics. There are further connections with hyperbolic geometry, combinatorics, smooth four-manifold topology, string theory, geometric representation theory and the Langlands program.

From a different direction, Heegaard-Floer homology is an invariant for low-dimensional manifolds whose discovery was inspired by gauge theory and its conjectural connections with symplectic geometry. Although this subject grew out of a different mathematical background from Khovanov's theory, the two subjects are clearly coalescing to illustrate topological quantum field theories in low-dimensional topology.

Workshops associated with the HTKL Program:

Workshop 1: Connections for Women: Homology Theories of Knots and Links
January 21, 2010 and January 22, 2010
Organized by Elisenda Grigsby (Columbia University), Olga Plamenevskaya (Stony Brook University), and Katrin Wehrheim (Massachusetts Institute of Technology)*

This two-day workshop served as a prelude to the introductory workshop for the semester-long program on homology theories of knots and links. Survey talks in the mornings positioned the work in Khovanov and Heegaard-Floer homology in a broader context, focusing on

- applications to classical questions in low-dimensional topology, and
- connections to contact and symplectic topology.

Research talks in the afternoons highlighted the range of current activity in the field. The organizers planned a format of no more than four talks each day in order to allow ample time for presentation opportunities for younger researchers and formal and informal discussions.

Workshop 2: Introductory Workshop: Homology Theories of Knots and Links
January 25, 2010 to January 29, 2010
Organized by Aaron Lauda (Columbia University), Robert Lipshitz (Columbia University), and Dylan Thurston (Barnard College, Columbia University)*

This workshop introduced the main branches in the study of knot homology theories. It consisted of three mini-courses, one on knot Floer homology and related topics, one on the various approaches to Khovanov and Khovanov-Rozansky homology, and one on categorification on quantum groups. (There were also several stand-alone lectures.) The techniques involved in the three branches are quite different; in particular, Heegaard-Floer theory is analytic in nature, with its origin in gauge theory and symplectic geometry, while both Khovanov homology and categorification are more algebraic in nature, with origins in representation theory and algebraic geometry. The workshop provided an opportunity for graduate students and researchers outside the field to gain entry, as well as for researchers working in one part of the field to learn about techniques and developments in other parts.

Workshop 3: Research Workshop: Homology Theories of Knots and Links
March 15, 2010 to March 19, 2010
Organized by Peter S. Ozsváth (Columbia University), Mikhail Khovanov (Columbia University), and Peter Teichner (University of California, Berkeley)*

Link homology is a young and rapidly-developing area drawing on many branches of mathematics. The subject has its roots in representation theory, and it has benefitted from its interactions with low-dimensional, classical, and quantum topology and symplectic geometry. Indeed, several recent developments have underscored the close parallels between link homology and Floer homological invariants for low-dimensional manifolds.

The aim of this conference was to study recent advances in categorification, link homology, Heegaard-Floer homology, and gauge theory. The workshop also focused on the interactions of these tools with low-dimensional topology, including knot theory and contact geometry.

HTKL Program Highlights

The aim of the program was to explore progress in homology theories of knots and links driven by the three mathematical currents of representation theory, gauge theory, and symplectic geometry and to study their interactions. The program came at a very exciting crossroads for the theory and helped to foster some breakthroughs in the subject. The program also benefitted greatly from interaction with the concurrent program on Symplectic and Contact Geometry and Topology. Owing in part to the richness and promise of link homology as a new tool in low-dimensional topology, the program attracted a large number of talented young mathematicians from all over the world and brought them together with leaders in the field. This proved to be beneficial both to the professional development of those young researchers and to the development of the subject.

The program included a postdoc seminar, a research seminar, several learning seminars (including a "Bordered Floer homology seminar working group") and a graduate students' seminar. Several of these working groups and seminars attracted participants from the SCGT program as well. Tomasz Mrowka gave a mini-course on his recent work with Peter Kronheimer, proving that Khovanov homology detects the unknot.

There were several workshop talks that dealt with applications of new techniques to older questions in topology. In this vein, Joshua Greene presented some exciting recent developments in the lens space realization problem, enumerating all lens spaces that are obtained as surgeries on knots in the three-sphere. This question first arose in a purely classical context (Dehn surgeries on knots in the three-sphere), but its solution uses tools from both Heegaard-Floer homology and Donaldson theory (gauge theory).

Other mathematical breakthroughs that occurred during the program include: Collin-Ghiggini-Honda and Kutluhan-Lee-Taubes's proof that "Embedded contact homology" (and, hence, by earlier work of Hutchings and Taubes, Seiberg-Witten homology) is isomorphic to Heegaard-Floer homology; the development of bordered Floer homology, an invariant for parametrized surfaces and three-manifolds with parameterized boundary, which can be used to compute Heegaard Floer homology for (closed) three-manifolds; categorification of quantum groups and their representations (Khovanov-Lauda, Rouquier, Webster) and Webster's categorification of Reshetikhin-Turaev tangle invariants; and Grigsby-Wehrli's discovery of a relation between sutured Floer homology and Khovanov homology.

Program 4: Complementary Program 2009-10 (CP)
August 17, 2009 to May 21, 2010

MSRI had a small Complementary Program comprised of two postdoctoral fellows (Christopher Hillar and Christopher Severs), one research professor, four research members, one graduate student, and four guests.

Christopher Hillar completed his second year as a postdoctoral fellow at MSRI. In 2009–10, he was a member of the Complementary Program for the fall semester and the External Postdoctoral Program for the spring semester. In the fall semester, Hillar's work was divided into two sections: Pure Mathematics and Theoretical Neuroscience.

In Pure Mathematics, Hillar finished up a large-scale computational project on the Secant Conjecture in Schubert calculus, proved the independent set conjecture in algebraic statistics using some infinite dimensional Groebner basis tools he had developed with Aschenbrenner, and studied the stabilization problems in toric algebra. In Neuroscience, Christopher Hillar developed a course with his mentor, Dr. Sommer, on neurologically plausible circuitry for clustering and memory.

Christopher Severs completed his Ph.D. at Arizona State University prior to joining MSRI's Complementary Program in 2009–10. Although he was not directly part of the Tropical Geometry Program, he was interested in this subject and participated in the activities of this program. At the same time, with Deputy Director Helene Barcelo and Ph.D. student Jacob White, he co-authored and submitted a journal article to the Transactions of the American Mathematical Society that was subsequently accepted for publication.

Severs also colaborated with fellow MSRI member, John Shareshian, from the Complementary Program and Einar Steingrimsson from the UC Berkeley. Though they had not submitted any papers, the collaboration with Steingrimsson led Severs to his next postdoctoral fellowship at Reykjavik University in Iceland.

1.4 Postdoctoral Program supported by the NSF supplemental grant DMS-0936277

In the Spring of 2009, MSRI (together with all the other NSF-funded mathematical institutions) proposed and received funds (DMS-0936277) for additional postdoctoral fellowships. This funding supported the research of talented junior future professors and leading research who otherwise might have left the profession due to the challenging economic climate. One of the most critical aspects of the development of a young mathematician's career is his or her assimilation into the culture and network of the established researchers in the field. Postdoctoral Fellowships (PdFs) present an unparalleled opportunity for junior mathematicians to meet, learn from, and collaborate with mentors in their chosen area.

The fellowships were open to U.S. junior researchers who had not been able to secure a position in academia within five years of obtaining a Ph.D. The search was also open to postdoctoral fellows that had already been selected to be in residence at MSRI for the duration of one MSRI's 2009–10 programs (Tropical Geometry, Symplectic and Contact Geometry and Topology, Homology Theories of Knots and Links) and who did not have a position awaiting them after their residency at MSRI.

Four (4) fellows were selected (from a pool of more than four hundred (400) US citizens or US permanent residents) for a 2-year postdoctoral fellowship starting in August 2009 and ending in May 2011. Two (2) fellows were awarded a 1-year postdoctoral fellowship starting in August 2010 and ending in May 2011. Each fellowship was hosted by the institution of the mentor designated in the application. No teaching duties were required of the fellows, but for those wanting to acquire some teaching experience, a maximum of one course per year was permitted.

Four (4) additional fellowships of one- to one-and-a-half years in length were awarded to MSRI postdoctoral fellows who had not been able to secure an academic position (by Spring 2009) after the end of their upcoming fellowship at MSRI. The award period depended on the length of their residency at MSRI during the academic year 2009–10. Each programmatic postdoctoral fellow was assigned a mentor upon arrival to MSRI, and this mentor's home institution hosted the fellow after the end of the stay at MSRI. MSRI referred to the programmatic postdoctoral fellows as *internal* and those funded by the supplemental grant as *external* postdoctoral fellows to distinguish them.

Please refer to the table below for the detailed status of each postdoc.

While most of the PdFs' time is spent at Sponsoring Institutions, the institute required commitments from all the mentors to follow MSRI mentoring guidelines. Below, we have listed those guidelines in detail.

Establishing a research plan:

- Designated weekly meeting
- A discussion at the beginning of the semester about the project(s) the PdF is pursuing and ideas about how to choose projects
- Introductions to senior researchers in the PdF's area
- Advice on how to write a paper well (point to literature on this subject); give feedback on paper drafts
- Advice about publication (e.g. how quickly to publish a thesis, choosing and dealing with journals, etc.)
- NSF grant proposal writing; feedback on proposal drafts, from beginning to submission

Planning for professional development:

- Advice on writing a CV and a research and teaching statements

- Advice on preparing for interviews
- Advice on how to give a lecture
- Have the PdF give a colloquium talk and critique the talk afterward; also advise on giving talks at national meetings, etc.
- Discussion on how to address the various aspects of an academic career (proportion of research/teaching/service at various stage of one's career; etc.)
- Discussion of teaching and mentoring issues; advice on textbooks; information on Project NExT

Biannual reports were also required. In addition to individual mentoring the fellows were invited to attend a 4-day workshop that focused on career skills. This workshop took place at AIM December 8–11, 2009 and emphasized resume writing, professional presentations, interviewing techniques, et cetera. Additionally, participants discussed and worked on developing on-the-job skills such as identifying and using mathematical resources, building a research program, writing grant proposals, directing research, and working in teams.

Here is the list of the 10 postdoctoral fellows with their dates as internal PD (when appropriate) and external PD, along with their hosting institution and mentor.

MSRI's 10 postdoctoral fellows in 2009-2011
Supported by the NSF Supplemental Grant

Name	PhD Year	Length of External Fellowship	Fall 2009	Spring 2010	Fall 2010	Spring 2011	Hosting Institute	Hosting Mentor
Angeltveit, Vigleik	2006	2 years	External	External	External	External	University of Chicago	Peter May
Bogart, Tristram	2007	1 year	Internal in TG	none	External	External	San Francisco State University	Federico Ardila
Crofts, Scott	2009	2 years	External	External	External	External	University of California, Santa Cruz	Martin Weissman
Dochtermann, Anton	2007	1 year	none	none	External	External	Stanford University	Gunnar Carlsson
Hillar, Christopher	2005	1.5 years	Internal in CP	External	External	External	Redwood Center (University of California, Berekeley)	Fritz Sommer
Katz, Eric	2004	1 year	Internal in TG	none	External	External	University of Texas, Austin	Sean Keel
Mahlburg, Karl	2006	2 years	External	External	External	External	Princeton University	Manjul Bhargava
Ma'u, Sikimeti	2008	1 year	Internal in SCGT	Internal in SCGT	External	External	Barnard College	Dusa McDuff
Smith, Abraham	2009	2 years	External	External	External	External	McGill University (Quebec)	Niky Karman
Speck, Jared	2008	1 year	none	none	External	External	Princeton University	Sergiu Klainerman

TG = Tropical Geometry Program
CP = Complementary Program 2009-10
SCGT = Symplectic and Contact Geometry and Topology Program

For a complete report on the four external postdoctoral fellows of 2009-10, please refer to the Appendix Chapter.

For a brief summary of all postdoctoral fellows (including internal postdocs), please refer Chapter 3.

1.5 Scientific Activities Directed at Underrepresented Groups in Mathematics

Connections for Women Workshops

During the 2009–10 academic year, MSRI hosted 3 Connections for Women workhops, one for each scientific program. The goal of these workshops was to facilitate networks among women and members of underrepresented minorities. For more information regarding each workshop, please refer to Section 1.3 above.

Math Institutes Modern Math Workshop (SACNAS)
Location: Dallas, Texas
October 14, 2009 to October 15, 2009
Organized by Ive Rubio (University of Puerto Rico in Humancao), Herbert Medina (Loyola Marymount University), Chehrzad Shakiban (University of Saint Thomas), and Mariel Vazquez (San Francisco State University)

This was the second workshop on contemporary research in mathematics sponsored by all the US-based Math Institutes. The topics of the workshop were related to programs that will occur in the Institutes during the academic year 2010–11. All presentations were expository, intended for mathematical scientists and students not necessarily working in these areas but who were interested in learning about new developments and the possibility of spending some time at one of the Math Institutes.

There was a 'mini course' for the undergraduate students on Wednesday, October 14, 2009. The topic of this mini course was *An Elementary Approach to Wavelets with Applications.*

On Thursday, October 15, there was a key note address by Rafael Irizarry who recently received the President's Award by the Committee of Presidents of Statistical Societies in "recognition of outstanding contributions to the statistics profession".

For a complete report on this activity, please refer to the Appendix Chapter.

MSRI-UP 2010: Elliptic Curves and Applications
June 12, 2010 to July 25, 2010
Organized by Duane Cooper (Morehouse College), Suzanne Weekes (Worcester Polytechnic Insitute), Ricardo Cortez (Tulane University), Ivelisse Rubio (University of Puerto Rico, Río Piedras) and Herbert Medina (Loyola Marymount University)*

The MSRI-UP was a comprehensive program for undergraduates that aimed at increasing the number of students from underrepresented groups in mathematics graduate programs. MSRI-UP included summer research opportunities, mentoring, workshops on the graduate school application process, and follow-up support.

More detailed information of MSRI-UP can be found in Chapter 5.

For a complete report on this activity, please refer to the Appendix Chapter.

1.6 Summer Graduate Schools (Summer 2009)

SGS 1: IAS/PCMI Summer Workshop: The Arithmetic of L-Functions
Location: IAS/Park City Mathematics Institute, Salt Lake City, UT
June 28, 2009 to July 18, 2009
Organized by Cristian Popescu (University of California, San Diego), Karl Rubin (University of California, Irvine), and Alice Silverberg (University of California, Irvine)*

An off-site workshop partially funded by MSRI.

SGS 2: Random Matrix Theory
July 06, 2009 to July 17, 2009
Organized by Jinho Baik (University of Michigan), Percy Deift(New York University), Toufic Suidan (University of Arizona), and Brian Rider (University of Colorado at Boulder)*

The goal of this workshop was two-fold:

- to describe many of the recent advances that have been made in the application of random matrix theory to problems in mathematics and physics and

- to develop some of the mathematical tools that are needed to enter the field.

Applications of random matrix theory are now being made to number theory, combinatorics, statistical physics, and statistics among other fields. The techniques employed in the field include methods from integrable systems, combinatorics, complex analysis, orthogonal polynomials, and, of course, random matrix theory per se.

SGS 3: Computational Theory of Real Reductive Groups
Location: Salt Lake City, Utah
July 20, 2009 to July 24, 2009
Organized by Jeffrey Adams (University of Maryland), Peter Trapa (University of Utah), Susana Salamanca (New Mexico State University), and John Stembridge (University of Michigan)*

The structure of real reductive algebraic groups is controlled by a remarkably simple combinatorial framework, generalizing the presentation of Coxeter groups by generators and relations. This framework in turn makes much of the infinite-dimensional representation theory of such groups amenable to computation.

The Atlas of Lie Groups and Representations project is devoted to looking at representation theory from this computationally informed perspective. The group (particularly Fokko du Cloux and Marc van Leeuwen) has written computer software aimed at supporting research in the field and at helping those who want to learn the subject.

The workshop explored this point of view in a lecture series aimed especially at graduate students and postdocs with only a modest background (such as the representation theory of compact Lie groups).

SGS 4: Inverse Problems
July 20, 2009 to July 31, 2009
Organized by Gunther Uhlmann (University of Washington)*

Inverse Problems are problems where causes for a desired or an observed effect are to be determined. They lie at the heart of scientific inquiry and technological development. Applications include a number of medical as well as other imaging techniques, location of oil and mineral deposits in the earth's substructure, creation of astrophysical images from telescope data, finding cracks and interfaces within materials, shape optimization, model identification in growth processes, and, more recently, modeling in the life sciences.

The workshop consisted of several minicourses addressing several of the theoretical and practical issues arising in inverse problems, including boundary rigidity and travel time tomography, cloaking and invisibility, electrical impedance imaging, statistical methods and biological applications, thermoacoustic and x-ray tomography, and resonances.

SGS 5: Symplectic and Contact Geometry and Topology
August 03, 2009 to August 14, 2009
Organized by John Etnyre (Georgia Institute of Technology), Dusa McDuff(Barnard College), and Lisa Traynor (Bryn Mawr College)*

Symplectic and Contact Topology has undergone rapid and exciting growth in the past few decades and is currently a rich subject, employing a variety of diverse techniques and touching on many areas of mathematics, such as algebraic and differential geometry, dynamical systems and low dimensional topology. This workshop is intended both for graduate students new to the area and for those working in the field.

Lectures in the first week introduced participants to basic topological, geometric and analytic techniques, including J-holomorphic curves. The second week discussed applications to symplectic geometry and to 3-dimensional topology and knot theory. A variety of discussion sessions in the afternoon catered to the differing interests of the students. Participants could stay for the Connections for Women and/or the Introductory Workshop to the year-long Symplectic Geometry program that began just after this workshop.

SGS 6: Toric Varieties
June 15, 2009 to June 26, 2009
Organized by David Cox(Amherst College) and Henry Schenck* (University of Illinois, Urbana)*

Toric varieties are algebraic varieties defined by combinatorial data, and there is a wonderful interplay between algebra, combinatorics, and geometry involved in their study. Many of the key concepts of abstract algebraic geometry (for example, constructing a variety by gluing affine pieces) have very concrete interpretations in the toric case, making toric varieties an ideal tool for introducing students to abstruse concepts.

The first week covered basic material, including affine toric varieties, projective toric varieties, normal toric varieties constructed from fans, divisors, and homogeneous coordinates. We also discussed toric surfaces.The second week went deeper into the subject, covering topics such as ampleness, vanishing theorems in cohomology, the secondary fan, and geometric invariant theory.

An important feature of the workshop was that it did not assume that students had a full background in algebraic geometry. Students knew basic facts about varieties in affine and projective space, but we assumed no knowledge of schemes, sheaves, cohomology, etc.

1.7 Other Scientific Workshops

Hot Topics: Black Holes in Relativity
September 14, 2009 to September 18, 2009
Organized by Mihalis Dafermos (University of Cambridge) and Igor Rodnianski (Princeton University)*

The mathematical study of the dynamics of the Einstein equations form a central part of both partial differential equations and geometry and is intimately related to our current physical understanding of gravitational collapse. The celebrated singularity theorems of Penrose, proven in the 1960s, showed that geodesic incompleteness is inevitable provided that initial data contain what is known as a closed trapped surface. Trapped surfaces are also related to the presence of black holes. A breakthrough in the understanding of trapped surface formation has recently been achieved by Christodoulou in his 600 page monograph *The formation of Black Holes in General Relativity*, Publications of the EMS, January 2009. In this monograph, it is shown that trapped surfaces form in evolution for the Einstein vacuum equations from completely dispersed initial configurations, a phenomenon caused purely by the focusing of gravitational waves. The proof brings together ideas from geometric analysis and non-linear hyperbolic equations and at the same time introduces new techniques adapted to large data problems. The methods will undoubtedly have many future applications in both general relativity and other equations of mathematical physics. In particular, the work provides the first global 'large data' result in general relativity (without symmetry assumptions) and opens the possibility for many new developments on dynamical problems relating to black holes.

Bay Area Differential Geometry Seminar
November 21, 2009 and April 17, 2010
Organized by Robert Bryant (MSRI), Joel Hass (UC Davis), David Hoffman (Stanford University), Rafe Mazzeo (Stanford University), and Richard Montgomery (UC Santa Cruz)*

The Bay Area Differential Geometry Seminar meets 3 times each year and is a 1-day seminar on recent developments in differential geometry and geometric analysis, broadly interpreted. Typically, it runs from mid-morning until late afternoon, with 3–4 speakers. Box lunches were available for purchase and the final talk was followed by a dinner.

Macaulay2
January 04, 2010 to January 08, 2010
Organized by David Eisenbud (University of California, Berkeley), Amelia Taylor (Colorado College), Hirotachi Abo (University of Idaho), Mike Stillman (Cornell University) and Dan Grayson (University of Illinois, Urbana-Champaign)*

Macaulay2 is a software system devoted to supporting research in algebraic geometry and commutative algebra. Its creation and development have been funded by the National Science Foundation since 1992. Macaulay2 includes core algorithms for computing Gröbner bases and graded or multi-graded free resolutions of modules over quotient rings of graded or multi-graded polynomial rings with a monomial ordering. The core algorithms are accessible through a versatile high level interpreted user language with a powerful debugger supporting the creation of new classes of mathematical objects and the installation of methods for computing specifically with them. Macaulay2 can compute Betti numbers, Ext, cohomology of coherent sheaves on projective varieties, primary decomposition of ideals, integral closure of rings, and more. The goal of the workshop was to work at improving and augmenting the functionality of some of the existing packages. Likely projects included computing sheaf cohomology, intersection theory, and enumerative geometry.

1.8 Educational & Outreach Activities

Summer Institute for the Professional Development of Middle School Teachers on Pre-Algebra (Wu Summer 2009 Institute)
July 06, 2009 to July 24, 2009
Organized by Hung-Hsi Wu (University of California, Berkeley), Stefanie Hassan (Little Lake City School District), Winnie Gilbert (Hacienda La Puente Unified School District), and Sunil Koswatta (Harper College)

This was a 14-day workshop on pre-algebra to be followed by 5 Saturday sessions spread over the 2009–10 school year. The main target was middle school teachers.

Bay Area Circle for Teachers
June 28, 2009 to July 02, 2009 and January 30, 2010
Organized by Brandy Wiegers (MSRI)

The aim of the Circle for Teachers is to equip educators with an effective problem-solving approach to teaching mathematics. This style of learning is based on the math circle environment, which has proven to be successful for students around the world. The workshop immersed a group of interested middle- and high-school math teachers in engaging mathematics and exposed them to a dynamic style of classroom presentation. Participants come away with a variety of resources, lesson modules, and a renewed sense of appreciation for the fascinating world of mathematics. Teachers were also eligible for continuing education credit, professional development units, or college course credits.

A major theme throughout the workshop was creatively answering the question of how to incorporate a problem-solving approach to math education into the existing curriculum. To this end, leaders supplied participants with handouts or short modules based on the material covered during their sessions. They also worked with teachers to share ideas for enlivening any math class and to develop lesson plans. Focused discussions were held regularly to determine what obstacles exist to incorporating this style of teaching into the present curriculum, what resources would be most helpful to teachers, and other related topics.

Circle on the Road (NSF Supplemental Grant DMS-0937701)
Location: Arizona State University, Tempe Campus, AZ
March 13, 2010 to March 15, 2010
Organized by Dave Auckly (MSRI), Matthias Kawski (Arizona State University), Omayra Ortega (Arizona State University), Hugo Rossi (University of Utah) and Mark Saul (Bronx High School, retired)

Circle on the Road was a workshop that MSRI sponsored to help spread math circles across the country. We invited both experienced math circle leaders and teams of people wishing to learn how to run math circles. Before the workshop, we assigned apprentices to eleven of the experienced circle leaders. Together, these teams planned sample circle sessions, exchanging e-mails and ideas before the workshop. The workshop began with a mathematics festival for students in the Phoenix metro area. More than 300 people attended this festival. After watching an experienced leader run a session in the morning, each apprentice took over and ran a session in the afternoon. Hands-on activities immediately captured the attention of participants of all ages. Visitors quickly transitioned from simply playing fun games to raising and exploring mathematical questions. Students, teachers, and math circle leaders alike enjoyed the festival. Student Nura Patani wrote, “It really was a fantastic festival! We all had a wonderful time and learned some very interesting things!” One student came 300 miles to attend the festival.

The following two days were packed with ten presentations, five panel discussions, and an evaluation session. Experienced leaders had the pleasure of participating, of learning new tricks and approaches, and of seeing old friends and meeting new ones. People new to the world of math circles came away with inspiration and looked forward to starting circles in the future. In addition to the circle started in Phoenix, teams from India, the Philippines, Minnesota, Oregon, North Carolina, Kentucky, Maryland, Arizona, and Texas were thinking about starting math circles in the fall. In total, twelve different teams wishing to start circles attended. Lesson plans and problems that were demonstrated at the workshop were posted on the National Association of Math Circles web page along with video from many of the presentations and activities from the festival. The new circles and the new resources that resulted from the workshop ensure that the positive effects of the workshop will continue for several more years.

Critical Issues in Mathematics Education: Reasoning and Sense-Making in the Math Curriculum (NSF Supplemental Grant DMS-0937701)

June 07, 2010 to June 09, 2010

*Organized by Scott Baldridge (Louisiana State University), Deborah Loewenberg Bal*l (University of Michigan), Aaron Bertram (University of Utah), Wade Ellis (West Valley Community College), Deborah Hughes Hallet (University of Arizona), Gary Martin (Auburn University), and William McCallum* (University of Arizona)*

The National Council of Teachers of Mathematics released a new document, *Focus in High School Mathematics: Reasoning and Sense-Making*. The Council of Chief State School Officers and the National Governors’ Association initiated a state-led effort to produce Common Core State Standards which they hoped would move states toward national curricular coherence. The national scene was being transformed through stimulus money aimed at having states adopt common standards. This was a significant time for mathematicians to weigh in for coherence and a focus on thinking, understanding and sense-making.

For these reasons, MSRI hosted the seventh Critical Issues in Mathematics Education Workshop on this topic. Themes of the workshop included international comparisons, the role of a coherent national curriculum in the teaching of mathematics, and the ways in which technology can be used to support reasoning and sense-making.

1.9 Programs Consultant List

Consultant Name(s)	Consultant Disciplinary Specialty	Consultant Employer	Activity Title
Deborah Ball	Education	University of Michigan	Educational workshops
David Bao	Differential geometry	San Francisco State University	Differential geometry seminar
Mathias Beck	Discrete geometry	San Francisco State University	Bay Area Circle for Teachers
Inez Fung	Climate change	University of California, Berkeley	Climate Change: Summer School & Economic Games and Mechanisms to Address Climate Change
Philip Griffith	Algebraic geometry	Institute for Advanced Study	Future program
Susan Hezlet		London Math. Society	Workshop on Mathematics Journals
Chris Jones	Climate change	University of North Carolina at Chapel Hill	Climate change: Summer School
Moris Kalka	Differential geometry	Tulane University	Summer Graduate Workshops
Rob Kirby	Topology	University of California, Berkeley	Open Access Journals
Jacob Lurie	Algebraic topology	Harvard University	Future program
William Macallum	Education	University of Arizona	Educational workshops
Rafe Mazzeo	Differential geometry	Stanford University	Differential geometry seminar
Donald McClure	Image processing	Brown University	AMS Open Access
Curt McMullen	Geometric quantization on the moduli spaces of flat SU(n) connections over surfaces		Future program
Robert Megginson	Analysis on math	University of Michigan	MSRI - UP
Juan Meza	Computational mathematics	Lawrence Berkeley National Laboratory	MSRI - UP
Richard Montgomery	Differential geometry	University of California, Santa Cruz	Differential geometry seminar
Assaf Naor	Probability	New York University	Quantative Geometry
Douglas Nychka	Climate change	National Center for Atmospheric Research	Climate Change: Summer School & Economic Games and Mechanisms to Address Climate Change
Jim Pitman	Statistics	University of California, Berkeley	Vmath
Bjorn Poonen	Model theory	Technology	Future program
Igor Rodnianski			Hot Topics: Black Holes in Relativity
Perter Sarnak	Number theory	University of Princeton	Future program
Mark Saul	Education	Education Development Center	Great Circles 2009
Tatiana Shubin	Number theory	San Jose State University	Bay Area Circle for Teachers
Ted Slaman	Logic	University of California, Berkeley	Future program
Zvesda Stankova	Algebraic geometry	Mill College	Bay Area Circle for Teachers
Sam Vandervelde	Number theory	St. Lawrence University	Great Circles 2009
Hung-Hsi Wu		University of California, Berkeley	Math. Professional Dev. Instiute (Wu Summer Institute)
Mary Lou Zeeman	Climate change	Bowdoin College	Toric Varieties
David Zetland	Climate change	University of California, Berkeley	Climate Change: Summer School
Educational Advisory Committee (EAC)			Teaching Undergraduates Mathematics
			Mathematics Teacher Education
Human Resources Advisory Committee (HRAC)			Math Institutes Modern Mathematics Workshop
			Mathematics: a National Forum
			MSRI - UP
Scientific Advisory Committee (SAC) & HRAC			Symplectic and Contact Geometry & Topology
			Tropical Geometry
			Homology Theories of Knots and Links
			Complementary Program

2. Program and Workshop Data

2.1 Program Participant List

(More detailed information can be found in the email attachment)

Last Name	First Name	Home Institution	Participant Role	Program
Abouzaid	Mohammed	MIT	Research Member	SCGT
Akian	Marianne	INRIA and Ecole Polytechnique	Research Member	TG
Angeltveit	Vigleik	University of Chicago	Postdoc	Ext. PD
Ardila	Federico	San Francisco State University	Research Member	TG
Auroux	Denis	University of California, Berkeley	Research Professor	SCGT
Baldridge	Scott	Louisiana State University	Research Member	HTKL
Baldwin	John	Princeton University	Research Member	HTKL
Baykur	Refik Inanc	Brandeis University	Research Member	HTKL
Benedetti	Bruno	TU Berlin	Research Member	HTKL
Berkovich	Vladimir	Weizmann Institute of Science	Research Professor	TG
Bertrand	Benoit	IUT Tarbes	Research Member	TG
Blanchet	Christian	Université de Paris VII (Denis Diderot)	Research Member	HTKL
Bloom	Jonathan	Columbia University	Program Associate	HTKL
Bogart	Tristram	Queen's University	Postdoc	TG
Brugalle	Erwan	Université de Paris VI (Pierre et Marie Curie)	Postdoc	TG
Buhovski	Lev	Tel Aviv University	Postdoc	SCGT
Buse	Olguta	Purdue University	Research Member	SCGT
Caprau	Carmen	California State University	Research Member	HTKL
Cautis	Sabin	Rice University	PD/RM	HTKL
Cieliebak	Kai	Ludwig-Maximilians-Universität München	Research Professor	SCGT
Cochran	Tim	Rice University	Research Member	HTKL
Cornea	Octav	University of Montreal	Research Professor	SCGT
Cotterill	Ethan	Max-Planck-Institut für Mathematik	Research Member	TG
Cotton-Clay	Andrew	Harvard University	PD/RM	SCGT
Crofts	Scott	University of Utah	Postdoc	Ext. PD
Cruickshank	James	National University of Ireland, Galway	Research Member	TG
Devadoss	Satyan	Williams College	Research Member	TG
Dickenstein	Alicia	University of Buenos Aires	Research Professor	TG
Diogo	Luis	Stanford University	Program Associate	SCGT
Draisma	Jan	Technische Universiteit Eindhoven	Research Member	TG
Eftekhary	Eaman	Institute for Studies in Theoretical Physics and Mathematics (IPM)	Research Member	HTKL
Eisenbud	David	University of California, Berkeley	Guest	CP
Eliashberg	Yakov	Stanford University	Organizer	SCGT
Etgu	Tolga	Koc University	Research Member	HTKL
Etnyre	John	Georgia Institute of Technology	Organizer	SCGT
Fabert	Oliver	Ludwig-Maximilians-Universität München	Postdoc	SCGT
Falk	Michael	Northern Arizona University	Research Member	TG
Feichtner	Eva	Universität Bremen	Organizer	TG
Feichtner-Kozlov	Dmitry	Universität Bremen	Research Member	TG
Felshtyn	Alexander	University of Szczecin	Research Member	SCGT
Finashin	Sergey	Middle East Technical University (ODTU)	Research Member	TG
Fish	Joel	Stanford University	Research Member	SCGT

Fomin	Sergey	University of Michigan	Research Member	TG
Fraser	Maia	National Polytechnic Institute	Research Member	SCGT
Frenk	Bart	Technische Universiteit Eindhoven	Program Associate	TG
Friedl	Stefan	university of Warwick	Research Member	HTKL
Fromm	Viktor	University of Durham	Program Associate	SCGT
Fukaya	Kenji	Kyoto University	Research Professor	SCGT
Gadbled	Agnès	Université de Neuchatel - Institut de Mathématiques	Postdoc	SCGT
Garay	Cristhian	Université de Paris VII (Denis Diderot)	Program Associate	TG
Gathmann	Andreas	University of Kaiserslautern	Research Professor	TG
Gaubert	Stephane	INRIA and Ecole Polytechnique	Research Member	TG
Gay	David	University of Cape Town	Research Member	HTKL
Georgieva	Penka	Stanford University	Program Associate	SCGT
Gerstenberger	Andreas	Ludwig-Maximilians-Universität München	Program Associate	SCGT
Ghiggini	Paolo	Université de Nantes	Research Member	HTKL
Gilmore	Allison	Columbia University	Program Associate	HTKL
Ginzburg	Viktor	University of California, Santa Cruz	Research Professor	SCGT
Giroux	Emmanuel	École Normale Supérieure de Lyon	Research Professor	SCGT
Givental	Alexander	University of California, Berkeley	Research Professor	SCGT
Goldin	Rebecca	George Mason University	Research Member	SCGT
Golovko	Roman	University of Southern California	Postdoc	SCGT
Greene	Joshua	Princeton University	PD/RM	HTKL
Grigoriev	Ilya	Stanford University	Program Associate	SCGT
Grigsby	Julia	Boston College	Postdoc	HTKL
Gross	Mark	University of California, San Diego	Research Professor	TG
Guilfoyle	Brendan	Institute of Technology Tralee	Research Member	SCGT
Gurel	Basak	Vanderbilt University	Research Member	SCGT
Haase	Christian	Math Dept, FU Berlin	Research Member	TG
Haebich	Mathias	Johann Wolfgang Goethe-Universität Frankfurt	Program Associate	TG
Harada	Megumi	McMaster University	Research Member	SCGT
Harvey	Shelly	Rice University	Research Member	HTKL
He	Jian	University of Southern California	Postdoc	SCGT
Hedden	Matthew	Massachusetts Institute of Technology	Research Member	HTKL
Hendricks	Kristen	Columbia University	Program Associate	HTKL
Herold	Matthias	TU Kaiserslautern	Program Associate	TG
Hillar	Christopher	University of California, Berkeley	Postdoc	CP
Hind	Richard	University of Notre Dame	Research Member	SCGT
Hohloch	Sonja	Stanford University	Research Member	SCGT
Holm	Tara	Cornell University	Research Member	SCGT
Hom	Jennifer	University of Pennsylvania	Program Associate	SCGT
Honda	Ko	Univ. of Southern California	Guest	CP
Horn	Peter	Columbia University	PD/RM	HTKL
Huang	Yang	University of Southern California	Program Associate	SCGT
Hutchings	Michael	University of California, Berkeley	Research Professor	SCGT
Ionel	Eleny-Nicoleta	Stanford University	Organizer	SCGT
Itenberg	Ilia	Institut de Recherche Math. Avancée de Strasbourg	Organizer	TG
Izhakian	Zur	Bar-Ilan University	Research Member	TG
Jensen	Anders	Georg-August-Universität zu Göttingen	Research Member	TG
Johansson	Petter	Stockholm University	Program Associate	TG

Jöricke	Burglind	Institut des Hautes Études Scientifiques (IHES)	Research Professor	CP
Juhasz	Andras	University of Cambridge	Research Member	HTKL
Kaliszewski	Stephen	Arizona State university	Guest	CP
Karaali	Gizem	Pomona College	Research Member	TG
Karshon	Yael	University of Toronto	Research Member	SCGT
Katz	Eric	University of Texas	Postdoc	TG
Katzarkov	Ludmil	University of Miami	Research Member	TG
Keem	Changho	Seoul National University	Research Member	CP
Kerman	Ely	University of Illinois at Urbana-Champaign	Research Member	SCGT
Kharlamov	Viatcheslav	Universite de Strasbourg, IRMA	Research Professor	TG
Khesin	Boris	University of Toronto	Research Member	SCGT
Khovanov	Mikhail	Columbia University	Organizer	HTKL
Klingenberg	Wilhelm	Durham University	Research Member	SCGT
Kol	Barak	Hebrew University	Research Member	TG
Kotschick	Dieter	Ludwig-Maximilians-Universität München	Research Member	SCGT
Krasner	Daniel	Columbia University	Postdoc	HTKL
Kutluhan	Cagatay	University of Michigan	Postdoc	HTKL
Latschev	Janko	Eidgenössische TH Zürich-Zentrum	Research Member	SCGT
Lauda	Aaron	Columbia University	Research Member	HTKL
Lee	Yi-Jen	Purdue University	Research Member	HTKL
Lekili	Yanki	University of Cambridge	Postdoc	HTKL
Levine	Adam	Columbia University	Program Associate	HTKL
Lewallen	Sam	Princeton University	Program Associate	HTKL
Leykin	Anton	Georgia Institute of Technology	Research Member	TG
Licata	Joan	Stanford University	Research Member	HTKL
Licata	Anthony	Stanford University	Research Member	HTKL
Lipshitz	Robert	Columbia University	Research Member	HTKL
Lisca	Paolo	Università di Pisa	Research Member	HTKL
Liu	Chiu-Chu	Columbia University	Research Member	SCGT
Lobb	Andrew	SUNY	Postdoc	HTKL
Lopez de Medrano	Lucia	National Autonomous University of Mexico	Postdoc	TG
Maclagan	Diane	University of Warwick	Research Member	TG
Mahlburg	Karl	Massachusetts Institute of Technology	Postdoc	Ext. PD
Mandini	Alessia	Technical University of Lisbon	Research Member	SCGT
Manolescu	Ciprian	University of California, Los Angeles	Research Professor	HTKL
Manon	Christopher	University of California, Berkeley	PD/RM	TG
Mark	Thomas	University of Virginia	Research Member	HTKL
Markwig	Hannah	Georg-August-Universität zu Göttingen	Research Member	TG
Mathews	Daniel	Stanford University	Research Member	SCGT
Matic	Gordana	University of Georgia	Research Member	SCGT
Ma'u	Sikimeti	Barnard College	Postdoc	SCGT
Maydanskiy	Maksim	Stanford University	PD/RM	SCGT
McDuff	Dusa	Barnard College	Organizer	HTKL
McLean	Mark	University of Cambridge	Postdoc	SCGT
McMullen	Curtis	Harvard University	Research Member	CP
Melvin	Paul	Bryn Mawr College	Research Member	HTKL
Meyer	Henning	Universität Kaiserslautern	Program Associate	TG
Mikhalkin	Grigory	Université de Genève	Organizer	TG
Mohnke	Klaus	Humboldt-Universität	Research Member	SCGT
Montgomery	Richard	UCSC	Research Professor	SCGT

Mrowka	Tomasz	MIT	Research Professor	HTKL
Murphy	Max	Stanford University	Program Associate	SCGT
Musiker	Gregg	University of Minnesota Twin Cities	PD/RM	TG
Ng	Lenhard	Duke University	Research Member	SCGT
Ni	Yi	California Institute of Technology	Research Member	HTKL
Nill	Benjamin	Freie Universität Berlin	Postdoc	TG
Nilsson	Lisa	Stockholm University	Research Member	TG
Nisse	Mounir	Université de Paris VI (Pierre et Marie Curie)	Postdoc	TG
Oh	Yong-Geun	University of Wisconsin	Research Member	SCGT
Ozbagci	Burak	Koc University	Research Member	SCGT
Ozsváth	Peter	Columbia University	Organizer	HTKL
Parker	Thomas	Michigan State University	Research Professor	SCGT
Parker	Brett	Universität Zürich	Postdoc	SCGT
Passare	Mikael	University of Stockholm	Research Professor	TG
Payne	Sam	Stanford University	PD/RM	TG
Pelayo	Alvaro	University of California, Berkeley	Research Member	SCGT
Petkova	Ina	Columbia University	Program Associate	HTKL
Pinsonnault	Martin	University of Western Ontario	Research Member	SCGT
Plamenevskaya	Olga	SUNY	Research Member	HTKL
Polterovich	Leonid	University of Chicago	Research Professor	SCGT
Pushkar	Petya	Université Libre de Bruxelles	Research Member	SCGT
Rasmussen	Jacob	Cambridge University	Research Professor	HTKL
Ratiu	Tudor	École Polytechnique Fédérale de Lausanne	Research Professor	SCGT
Rau	Johannes	Technische Universitaet Kaiserslautern	Program Associate	TG
Rezazadegan	Reza	Aarhus University	Research Member	HTKL
Risler	Jean-Jacques	Université de Paris VI (Pierre et Marie Curie)	Research Member	TG
Roberts	Rachel	Washington University in St. Louis	Research Member	HTKL
Roberts	Lawrence	Michigan State University	Research Member	HTKL
Roger	Claude	Université Claude-Bernard (Lyon I)	Research Member	SCGT
Rojkovskaia	Natalia	Kansas State University	Research Member	TG
Rossi	Paolo	École Polytechnique	Research Member	SCGT
Rozansky	Lev	University of North Carolina	Organizer	HTKL
Ruan	Yongbin	University of Michigan	Research Professor	SCGT
Russell	Heather	Louisiana State University	Research Member	HTKL
Sabloff	Joshua	Haverford College	Research Member	SCGT
Sandon	Sheila	Université de Nantes	Research Member	SCGT
Sarkar	Sucharit	Princeton University	PD/RM	HTKL
Savelyev	Yakov	University of Massachusets, Amherst	Postdoc	SCGT
Sazdanovic	Radmila	The George Washington University	Postdoc	HTKL
Schoenfeld	Eric	Stanford University	Research Member	SCGT
Schroeter	Franziska	Georg-August-Universität zu Göttingen	Program Associate	TG
Seidel	Paul	Massachusetts Institute of Technology	Organizer	SCGT
Severs	Christopher	Arizona State University	Postdoc	CP
Shareshian	John	Washington University in St. Louis	Research Member	CP
Shaw	Kristin	University of Toronto	Program Associate	TG
Sheikhalishahi	Akram	Sharif University of Technology	Program Associate	HTKL
Shustin	Eugenii	Tel Aviv University	Research Member	TG
Siebert	Bernd	Universität Hamburg	Research Member	TG
Slawinski	Mike	University of California, San Diego	Program Associate	TG
Smith	Abraham	Duke University	Postdoc	Ext. PD

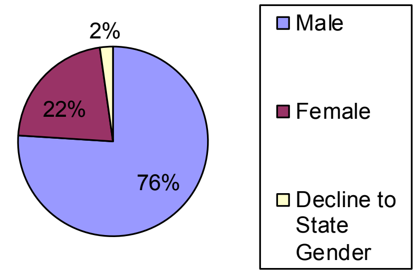
Smith	Ivan	Centre for Mathematical Sciences	Research Professor	SCGT
Stapledon	Alan	University of Michigan	Postdoc	TG
Steingrimsson	Einar	Reykjavik University	Research Member	CP
Stipsicz	András	Hungarian Academy of Sciences (MTA)	Research Professor	HTKL
Stroppel	Catharina	Universität Bonn	Research Professor	HTKL
Sturmfels	Bernd	UCB - University of California, Berkeley	Organizer	TG
Sullivan	Michael	University of Massachusetts	Research Member	SCGT
Szabo	Zoltan	Princeton University	Organizer	HTKL
Tabera	Luis	University of California, Berkeley	PD/RM	TG
Taubes	Clifford	Harvard University	Guest	CP
Teichner	Peter	University of California, Berkeley	Research Professor	HTKL
Thurston	Dylan	Barnard College	Organizer	HTKL
Tolman	Susan	University of Illinois at Urbana-Champaign	Research Member	SCGT
Tosun	Bulent	Georgia Insitute of Technology	Program Associate	SCGT
Traynor	Lisa	Bryn Mawr College	Research Member	SCGT
Tsai	Chung-Jun	Harvard University	Program Associate	CP
Van Horn-Morris	Jeremy	AIM	Research Member	SCGT
Vaz	Pedro	Technical University of Lisbon	Research Member	HTKL
Vela-Vick	David	Columbia University	PD/RM	HTKL
Vertesi	Vera	Alfred Renyi Institute of Mathematics	Postdoc	HTKL
Viro	Oleg	SUNY	Research Member	HTKL
Viterbo	Claude	École Polytechnique	Research Member	SCGT
Vogel	Thomas	Max-Planck-Institut für Mathematik	Research Member	SCGT
Watson	Liam	University of California, Los Angeles	Research Member	HTKL
Weber	Joachim	Humboldt-Universität	Research Member	SCGT
Wehrheim	Katrin	Massachusetts Institute of Technology	Research Member	SCGT
Wehrli	Stephan	Université de Paris VII (Denis Diderot)	Postdoc	HTKL
Werner	Annette	Universität Frankfurt	Research Professor	TG
Williams	Lauren	University of California, Berkeley	Postdoc	TG
Woodward	Christopher	Rutgers University	Research Member	SCGT
Yonezawa	Yasuyoshi	Nagoya University	Research Member	HTKL
Yu	Josephine	Massachusetts Institute of Technology	PD/RM	TG
Zarev	Rumen	Columbia University	Program Associate	HTKL
Zharkov	Ilia	Kansas State University	Research Member	TG
Zvonkine	Dimitri	Stanford University	Research Member	SCGT

2.2 Program Participant Summary

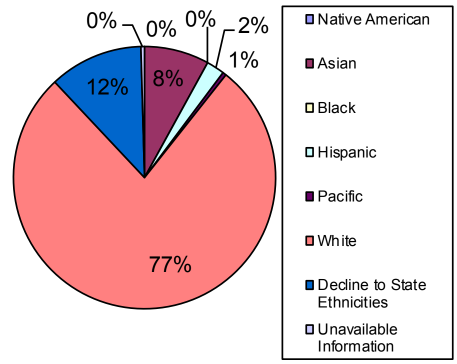
Programs	# of Members	# of Citizens & Perm. Res.	%	# of Female	%	# of Minorities	%	US Home Institution	%
Symplectic and Contact Geometry and Topology	94	47	*50.0%*	21	*22.3%*	1	*2.1%*	56	59.6%
Tropical Geometry	62	23	*37.1%*	14	*22.6%*	1	*4.3%*	21	33.9%
Homology Theory of Knots and Links	66	39	*59.1%*	15	*22.7%*	1	*2.6%*	47	71.2%
Complementary Program 2009-10	12	8	*66.7%*	1	*8.3%*	1	*12.5%*	9	75.0%
External Postdoctoral Fellows Program 2009-10	5	5	*100.0%*	0	*0.0%*	1	*20.0%*	5	100.0%
Total # of *Distinct* Members	**225**	**113**	***50.2%***	**49**	***21.8%***	**4**	***3.5%***	**129**	***57.3%***

2.3 Program Participant Demographic Data

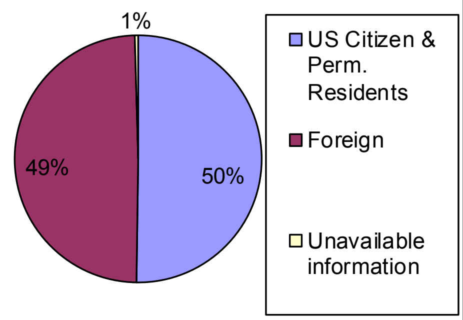
Gender	#	% (No Decl.)*	%
No. of Distinct Members	225		100.0%
Male	171	77.73%	76.0%
Female	49	22.27%	21.8%
Decline to State Gender	5		2.2%



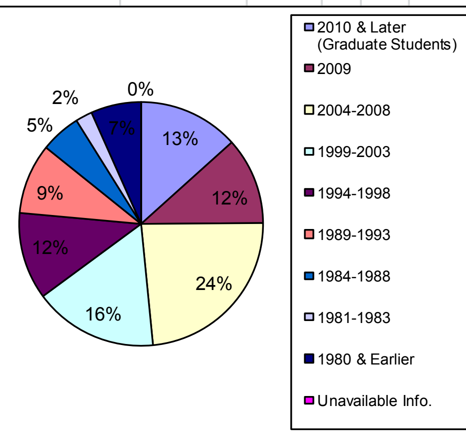
Ethnicities	#	% (No Decl.)*	%
Native American	0	0.00%	0.0%
Asian	18	9.09%	8.0%
Black	0	0.00%	0.0%
Hispanic	5	2.53%	2.2%
Pacific	1	0.51%	0.4%
White	174	87.88%	77.3%
Decline to State Ethnicities	26		11.6%
Unavailable Information	1		0.4%
No. of Distinct Members	225		100.0%
Minorities	4		3.5%



Citizenships	#		%
US Citizen & Perm. Residents	113		50.2%
Foreign	111		49.3%
Unavailable information	1		0.4%
No. of Distinct Members	225		100.0%
US Citizen	87		38.7%
Perm Residents	26		11.6%
Home Inst. in US	129		57.33%



Year of Ph.D	#		%
2010 & Later (Graduate Students)	30		13.3%
2009	26		11.6%
2004-2008	53		23.6%
1999-2003	37		16.4%
1994-1998	26		11.6%
1989-1993	21		9.3%
1984-1988	12		5.3%
1981-1983	5		2.2%
1980 & Earlier	15		6.7%
Unavailable Info.	0		0.0%
Total	225		100.0%



Statistic Calculation based on all participants that did not decline.

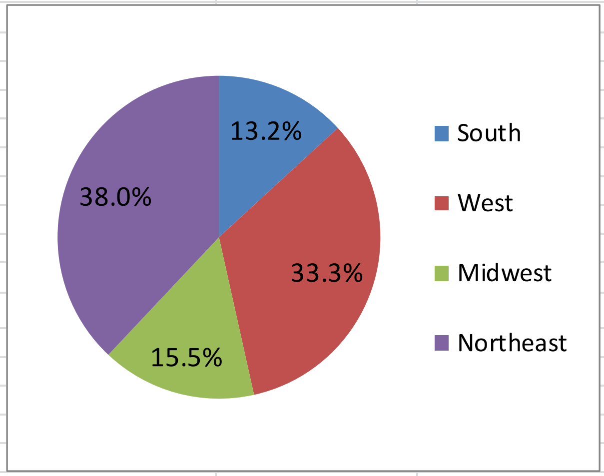
5 Programs of 2009-10

Symplectic and Contact Geometry and Topology
Tropical Geometry
Homology Theory of Knots and Links
Complementary Program 2009-10
External Postdoctoral Fellows Program 2009-10

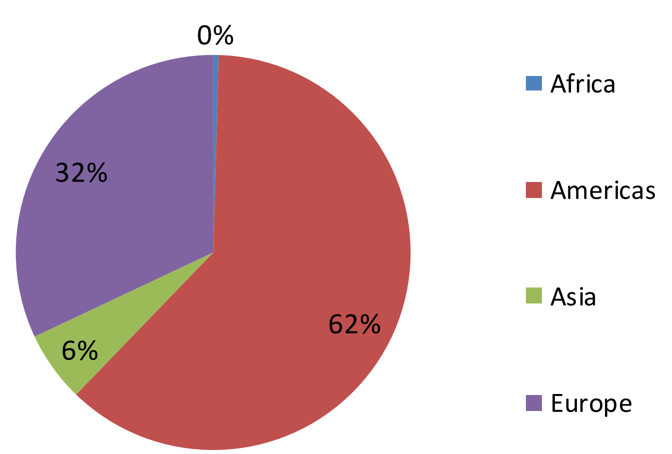
Home Institution Classified by States

**Regions based on US Census classification*

State	#	%	2007 Census
South	**17**	**13.2%**	**36.6%**
AL	-	0.0%	1.5%
AR	-	0.0%	0.9%
DE	-	0.0%	0.3%
DC	1	0.8%	0.2%
FL	1	0.8%	6.1%
GA	4	3.1%	3.2%
KY	-	0.0%	1.4%
LA	1	0.8%	1.4%
MD	-	0.0%	1.9%
MS	-	0.0%	1.0%
NC	3	2.3%	3.0%
OK	-	0.0%	1.2%
SC	-	0.0%	1.5%
TN	1	0.8%	2.0%
TX	4	3.1%	7.9%
VA	2	1.6%	2.6%
WV	-	0.0%	0.6%
West	**43**	**33.3%**	**23.2%**
AK	-	0.0%	0.2%
AZ	3	2.3%	2.1%
HI	-	0.0%	0.4%
ID	-	0.0%	0.5%
MT	-	0.0%	0.3%
CA	39	30.2%	12.1%
CO	-	0.0%	1.6%
NV	-	0.0%	0.9%
NM	-	0.0%	0.7%
OR	-	0.0%	1.2%
UT	1	0.8%	0.9%
WA	-	0.0%	2.1%
WY	-	0.0%	0.2%
Midwest	**20**	**15.5%**	**22.0%**
IL	4	3.1%	4.3%
IN	3	2.3%	2.1%
IA	1	0.8%	1.0%
KS	2	1.6%	0.9%
MI	7	5.4%	3.3%
MN	-	0.0%	1.7%
MO	2	1.6%	1.9%
ND	-	0.0%	0.2%
NE	-	0.0%	0.6%
OH	-	0.0%	3.8%
SD	-	0.0%	0.3%
WI	1	0.8%	1.9%
Northeast	**49**	**38.0%**	**18.1%**
CT	-	0.0%	1.2%
ME	-	0.0%	0.4%
MA	18	14.0%	2.1%
NH	-	0.0%	0.4%
NJ	6	4.7%	2.9%
NY	21	16.3%	6.4%
PA	4	3.1%	4.1%
RI	-	0.0%	0.4%
VT	-	0.0%	0.2%
Total	**129**	**100%**	**100%**



Home Institution Classified by Countries			
**Regions based on United Nations classification*			
Africa			1
	Southern Africa		**1**
		South Africa	1
Americas			139
	Central America		**2**
		Mexico	2
	North America		**136**
		Canada	7
		United States	129
	South America		**1**
		Argentina	1
Asia			13
	Eastern Asia		**3**
		Japan	2
		Korea, Republic of	1
	South-central Asia		**2**
		Iran, Islamic Republi	2
	Western Asia		**8**
		Israel	5
		Turkey	3
Europe			72
	Eastern Europe		**3**
		Hungary	2
		Poland	1
	Northern Europe		**16**
		Denmark	1
		England	9
		Iceland	1
		Ireland	2
		Sweden	3
	Southern Europe		**3**
		Italy	1
		Portugal	2
	Western Europe		**50**
		Belgium	1
		France	19
		Germany	24
		Netherlands	2
		Switzerland	4
Grand Total			**225**

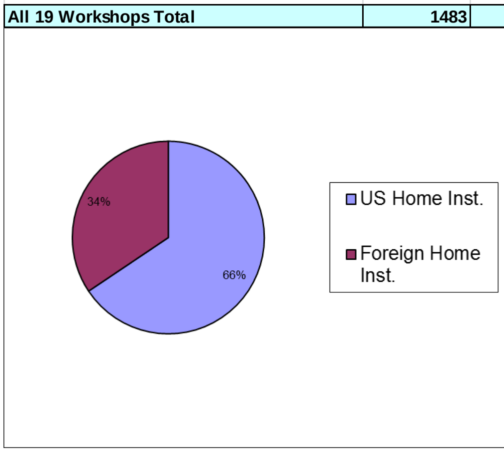


2.4 Workshop Participant List

(See e-mail attached file)

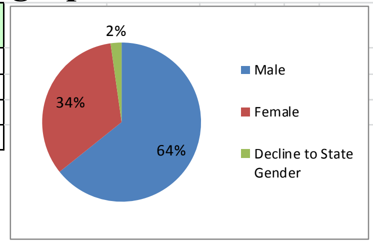
2.5 Workshop Participant Summary

Name of Activity	# of Participants	# of Citizens & Permanent Residents	%	# of Female	%	#. of Minorities	%	US Home Institution	%
16 Scientific Workshops									
Connections for Women: Tropical Geometry	75	31	41%	47	63%	3	10%	41	55%
Introductory Workshop: Tropical Geometry	106	42	40%	36	34%	2	5%	52	49%
Tropical Geometry in Combinatorics and Algebra	91	40	44%	28	31%	3	8%	40	44%
Tropical Structures in Geometry and Physics	84	34	40%	16	19%	2	6%	36	43%
Algebraic Structures in the Theory of Holomorphic Curves	103	41	40%	15	15%	2	5%	57	55%
Symplectic and Contact Topology and Dynamics: Puzzles and Horizons	127	50	39%	35	28%	0	0%	75	59%
Connections for Women: Symplectic and Contact Geometry and Topology	34	14	41%	30	88%	0	0%	19	56%
Introductory Workshop: Symplectic and Contact Geometry and Topology	105	40	38%	28	27%	1	3%	63	60%
Symplectic and Poisson Geometry in interaction with Algebra, Analysis and Topology	76	39	51%	13	17%	1	3%	49	64%
Symplectic Geometry, Noncommutative Geometry and Physics	78	34	44%	14	18%	1	3%	42	54%
Connections for Women: Homology Theories of Knots and Links	59	40	68%	49	83%	2	5%	47	80%
Introductory Workshop: Homology Theories of Knots and Links	111	77	69%	39	35%	5	6%	95	86%
Research Workshop: Homology Theories of Knots and Links	137	82	60%	34	25%	4	5%	107	78%
Hot Topics: Black Holes in Relativity	53	25	47%	11	21%	1	4%	40	75%
Bay Area Differential Geometry Seminar (November 2009)	14	8	57%	1	7%	1	13%	8	57%
Bay Area Differential Geometry Seminar (April 2010)	25	12	48%	3	12%	0	0%	12	48%
16 Scientific Workshops Total	**1278**	**609**	**48%**	**399**	**31%**	**28**	**5%**	**783**	**61%**
3 Outreach & Diversity Workshops									
Summer Institute for the Professional Development of Middle School Teachers on Pre-Algebra (Wu Summer Institute July 2009)	25	24	96%	17	68%	1	4%	25	100%
Critical Issues in Mathematics Education: Reasoning and Sense-Making in the Math Curriculum	99	86	87%	46	46%	12	14%	91	92%
Circle on the Road (March 2010)	81	73	90%	35	43%	6	8%	74	91%
3 Outreach & Diversity Workshops Total	**205**	**183**	**89%**	**98**	**48%**	**19**	**10%**	**190**	**93%**
All 19 Workshops Total	**1483**	**792**	**53%**	**497**	**34%**	**47**	**6%**	**973**	**66%**

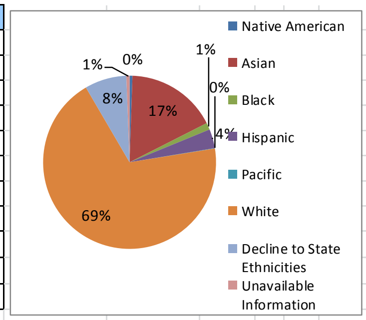


2.6 Workshop Participant Demographic Data

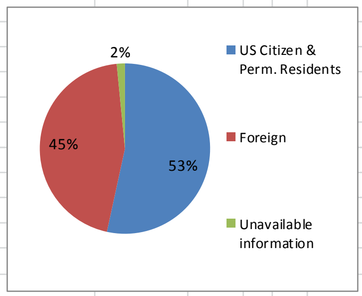
Gender	#	% (No Decl.)*	%
# of Participants	1483		100.0%
Male	953	65.72%	64.3%
Female	497	34.28%	33.5%
Decline to State Gender	33		2.2%



Ethnicities	#	% (No Decl.)*	%
Native American	8	0.59%	0.5%
Asian	252	18.56%	17.0%
Black	19	1.40%	1.3%
Hispanic	53	3.90%	3.6%
Pacific	1	0.07%	0.1%
White	1025	75.48%	69.1%
Decline to State Ethnicities	116		7.8%
Unavailable Information	9		0.6%
Total # of participants	1483		100.0%
Minorities	47		5.9%

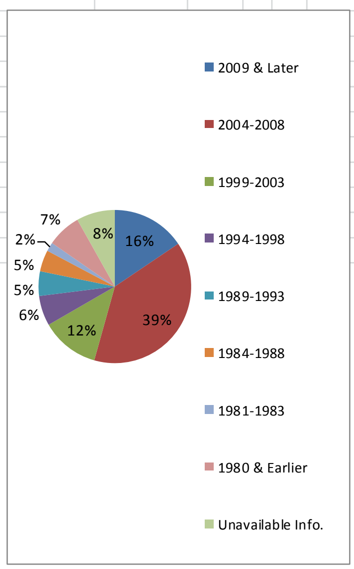


Citizenships	#		%
US Citizen & Perm. Residents	792		53.4%
Foreign	668		45.0%
Unavailable information	23		1.6%
# of participants	1483		100.0%
US Citizen	685		46.2%
Perm Residents	107		7.2%
Home Inst. in US	973		65.61%



Year of Highest Degree	#		%
2009 & Later	231		15.6%
2004-2008	575		38.8%
1999-2003	183		12.3%
1994-1998	94		6.3%
1989-1993	77		5.2%
1984-1988	67		4.5%
1981-1983	28		1.9%
1980 & Earlier	107		7.2%
Unavailable Info.	121		8.2%
Total # of participants	1483		100.0%

**Statistic Calculation based on all participants that did not decline.*



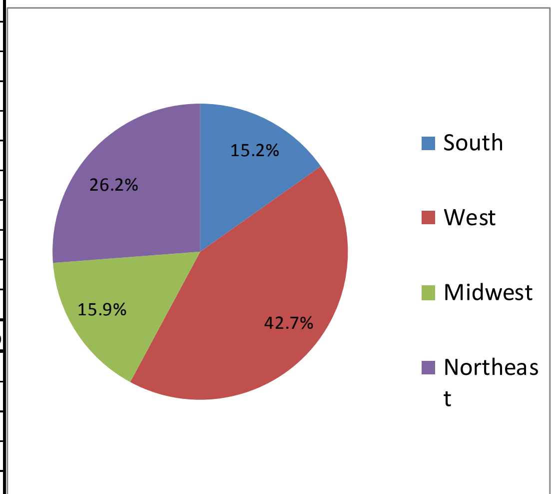
19 workshops in 2009-10

Connections for Women: Tropical Geometry
Introductory Workshop: Tropical Geometry
Tropical Geometry in Combinatorics and Algebra
Tropical Structures in Geometry and Physics
Algebraic Structures in the Theory of Holomorphic Curves
Symplectic and Contact Topology and Dynamics: Puzzles and Horizons
Connections for Women: Symplectic and Contact Geometry and Topology
Connections for Women: Homology Theories of Knots and Links
Introductory Workshop: Homology Theories of Knots and Links
Research Workshop: Homology Theories of Knots and Links
Hot Topics: Black Holes in Relativity
Wu Summer Institute (July 2009)
Bay Area Differential Geometry Seminar (November 2009)
Critical Issues in Mathematics Education: Reasoning and Sense-Making in the Math Curriculum
Circle on the Road (March 2010)
Bay Area Differential Geometry Seminar (April 2010)

Home Institution Classified by States

**Regions based on US Census classification*

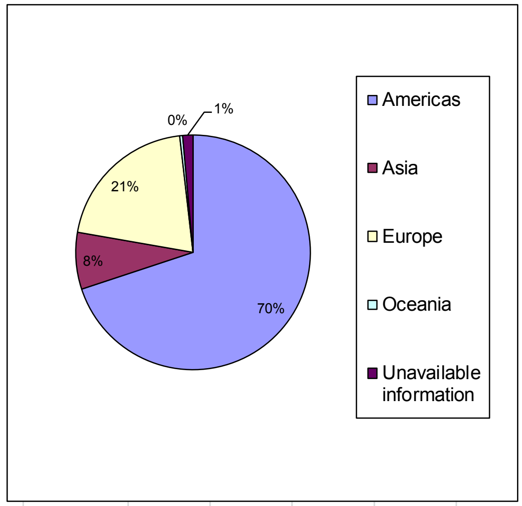
State	#	%	2007 Census
South	**148**	**15.2%**	**36.6%**
AL	5	0.5%	1.5%
AR	-	0.0%	0.9%
DE	1	0.1%	0.3%
DC	9	0.9%	0.2%
FL	4	0.4%	6.1%
GA	38	3.9%	3.2%
KY	2	0.2%	1.4%
LA	12	1.2%	1.4%
MD	6	0.6%	1.9%
MS	-	0.0%	1.0%
NC	20	2.1%	3.0%
OK	1	0.1%	1.2%
SC	-	0.0%	1.5%
TN	3	0.3%	2.0%
TX	35	3.6%	7.9%
VA	12	1.2%	2.6%
WV	-	0.0%	0.6%
West	**415**	**42.7%**	**23.2%**
AK	-	0.0%	0.2%
AZ	20	2.1%	2.1%
HI	1	0.1%	0.4%
ID	-	0.0%	0.5%
MT	1	0.1%	0.3%
CA	352	36.2%	12.1%
CO	4	0.4%	1.6%
NV	-	0.0%	0.9%
NM	1	0.1%	0.7%
OR	19	2.0%	1.2%
UT	4	0.4%	0.9%
WA	12	1.2%	2.1%
WY	1	0.1%	0.2%
Midwest	**155**	**15.9%**	**22.0%**
IL	29	3.0%	4.3%
IN	22	2.3%	2.1%
IA	16	1.6%	1.0%
KS	8	0.8%	0.9%
MI	33	3.4%	3.3%
MN	21	2.2%	1.7%
MO	4	0.4%	1.9%
ND	-	0.0%	0.2%
NE	-	0.0%	0.6%
OH	4	0.4%	3.8%
SD	-	0.0%	0.3%
WI	18	1.8%	1.9%
Northeast	**255**	**26.2%**	**18.1%**
CT	9	0.9%	1.2%
ME	-	0.0%	0.4%
MA	105	10.8%	2.1%
NH	-	0.0%	0.4%
NJ	29	3.0%	2.9%
NY	85	8.7%	6.4%
PA	21	2.2%	4.1%
RI	4	0.4%	0.4%
VT	2	0.2%	0.2%
Total	**973**	**100%**	**100%**



Home Institution Classified by Countries

**Regions based on United Nations classification*

Americas			**1037**
	Central America		**9**
		El Salvador	1
		Mexico	8
	North America		**1015**
		Canada	42
		United States	973
	South America		**13**
		Argentina	7
		Brazil	5
		Colombia	1
Asia			**116**
	Eastern Asia		**67**
		China	7
		Japan	37
		Korea, Republic of	17
		Taiwan	6
	South-central Asia		**5**
		India	2
		Iran, Islamic Republic of	3
	South-eastern Asia		**7**
		Philippines	4
		Singapore	3
	Western Asia		**37**
		Israel	26
		Turkey	11
Europe			**303**
	Eastern Europe		**9**
		Czech Republic	1
		Hungary	1
		Poland	4
		Russian Federation	3
	Northern Europe		**64**
		Denmark	2
		England	32
		Iceland	4
		Ireland	10
		Norway	1
		Sweden	15
	Southern Europe		**21**
		Italy	10
		Portugal	9
		Slovenia	2
	Western Europe		**209**
		Austria	1
		Belgium	5
		France	63
		Germany	104
		Luxembourg	2
		Netherlands	4
		Spain	4
		Switzerland	26
Oceania			**6**
	Australia and New Zealand		**6**
		Australia	6
Unavailable information			21
Grand Total			**1483**



2.7 Program Publication List

Last Name	First Name	Publication Title	Co-authors	Status
Ardila	Federico	Matroid polytopes and their volumes	C. Benedetti and J. Doker	appeared
Ardila	Federico	Root polytopes and growth series of root lattices	M, Beck, S. Hosten, J. Pfeifle, and K. Seashore	appeared
Ardila	Federico	Tilings	R. Stanley	appeared
Cochran	Tim	Derivatives of Knots and second order signatures	Shelly harvey and Constnace Leidy	appeared
Cornea	Octav	Rigidity and uniruling for Lagrangian Submanifolds	Paul Biran	appeared
Devadoss	Satyan	(BOOK) Discrete and Computational Geometry	Joe O'Rourke	appeared
Devadoss	Satyan	Particle Collisions on Graphs	Rahul Shah	appeared
Eliashberg	Yakov	Topology of spaces of S-immersions	Mishachev	appeared
Etgu	Tolga	Examples of planar tight contact structures with support norm one	Yanki Lekili	appeared
Felshtyn	Alexander	Twisted conjugacy classes in symplectic groups, mapping class groups and braids groups(with appendix written jointly with Francois Dahmani	Daciberg Goncalves	appeared
Ginzburg	Viktor	Hamiltonian Dynamics and Symplectic Topology	Basak Gurel and Symplectic Topology	appeared
Gross	Mark	Quivers, curves and the tropical vertex	Rahul Pandharipande	appeared
Gross	Mark	The Tropical Vertex	Rahul Pandharipande; Bernd Siebert	appeared
Gross	Mark	Tropical geometry and mirror symmetry for P^2		appeared
Hedden	Matthew	Manifolds with small Heegaard Floer ranks	Yi Ni	appeared
Hutchings	Michael	Embedded contact homology and its applications		appeared
Leykin	Anton	Certified Numerical Homotopy Tracking	Carlos Beltran	appeared
Licata	Anthony	Heisenberg Algebras and Hilbert Schemes	Sabin Cautis	appeared
Lopez de Medrano	Lucia	Puiseux power series solutions for systems of equations	Fuensanta Aroca, Giovanna Ilardi	appeared
Lopez de Medrano	Lucia	Recursive formulas for Welschinger invariants	Aubin Arroyo, Erwan Brugalle	appeared
McDuff	Dusa	Displacing Lagrangian submanifolds via probes	none	appeared
Melvin	Paul	The Milnor degree of a 3-manifold	Tim Cochran	appeared
Montgomery	Richard	Review of `Sub-Riemannian Geometry'		appeared
Musiker	Gregg	Cluster expansion formulas and perfect matchings	Ralf Schiffler	appeared
Nill	Benjamin	Factorial Gorenstein toric Fano varieties with large Picard number	Mikkel Oebro (Aarhus)	appeared
Pelayo	Alvaro	Applying Hodge theory to detect hamiltonian flows	Tudor S Ratiu	appeared

Pelayo	Alvaro	Hamiltonian dynamics and spectral theory for spin oscillators	San Vu Ngoc	appeared
Plamenevskaya	Olga	Khovanov homology, open books, and tight contact structures	John Baldwin	appeared
Rasmussen	Jacob	The decategorification of sutured Floer homology	Stefan Friedl, Andras Juhas	appeared
Severs	Christopher	k-Parabolic Subspace Arrangments	Helene Barcelo, Jacob White	appeared
Shareshian	John	Eulerian quasisymmetric functions	MIchelle Wachs	appeared
Shareshian	John	Eulerian quasisymmetric functions and cyclic sieving	Bruce Sagan, Michelle Wachs	appeared
Shareshian	John	Non-right orderable 3-manifold groups	Rachel Roberts	appeared
Stipsicz	András	Contact surgeries and transverse knot invariants in Heegaard Floer homology	P. Ozsvath	appeared
Stroppel	Catharina	2-block Springer fibres and convolution algebras	Ben Webster	appeared
Sullivan	Michael	Link Floer Homology and Surface Invariants	Matt Hedden	appeared
Thurston	Dylan	Characterizing generic global rigidity	Alex Healy and Steven Gortler	appeared
Van Horn-Morris	Jeremy	Fibered Transverse Knots and the Bennequin Bound	John Etnyre	appeared
Vertesi	Vera	Legnedrian Classification of twist knots	Etnyre, Ng	appeared
Viro	Oleg	On basic notions of tropical geometry		appeared
Williams	Lauren	Staircase tableaux, the ASEP, and Askey-Wilson polynomials	Sylvie Corteel	appeared
Abouzaid	Mohammed	A cotangent fibre generates the Fukaya category		submitted
Bogart	Tristram	Small Chvatal Rank	Annie Raymond, Rekha Thomas	submitted
Buse	Olguta	Negative inflation and symplectomorphism groups of ruled surfaces		submitted
Draisma	Jan	Partition Arguments in Multiparty Communication Complexity	Eyal Kushilevitz, and Enav Weinreb	submitted
Draisma	Jan	Singular lines of trilinear forms	Ron Shaw	submitted
Draisma	Jan	Trek separation for Gaussian graphical models	Seth Sullivant, Kelli Talaska	submitted
Eliashberg	Yakov	Effect of Legendrian surgery	Bourgeois, Ekholm, Ganatra, Maydanskiy	submitted
Etgu	Tolga	Tight contact structures on laminar free hyperbolic three-manifolds		submitted
Etnyre	John	Cabling, contact structures and mapping class monoids	Kenneth L. Baker, Jeremy Van Horn-Morris	submitted
Etnyre	John	Legendrian and transverse twist knots	Lenhard Ng and Vera V\'ertesi	submitted
Feichtner-Kozlov	Dmitry	Discrete Morse Theory and Hopf bundle		submitted
Gadbled	Agnès	Families of monotone symplectic manifolds constructed via symplectic cut and their Lagrangian submanifolds		submitted

Ghiggini	Paolo	Sutures and contact homology I	Vincent Colin, Ko Honda, Michael Hutchings	submitted
Givental	Alexander	Soliton equations, vertex operators, and simple singularities	E. Frenkel, T. Milanov	submitted
Goldin	Rebecca	Torsion in the Full Orbifold K-theory of abelian symplectic quotients	Tara Holm, Megumi Harada	submitted
Gross	Mark	Mirror symmetry via logarithmic degeneration data II	Bernd Siebert	submitted
Hedden	Matthew	On sutured Floer homology and the equivalence of Seifert surfaces	Andras Juhasz, Sucharit Sarkar	submitted
Hind	Richard	New obstructions to symplectic embeddings	Ely Kerman	submitted
Hohloch	Sonja	Floer homology and homoclinic points		submitted
Hom	Jennifer	A note on cabling and L-space surgeries		submitted
Izhakian	Zur	Supertropical Matrix Algebra II: Solving Tropical Equations	Louis Rowen	submitted
Khesin	Boris	Contact complete integrability	Serge Tabachnikov	submitted
Klingenberg	Wilhelm	Proof of the Caratheodory Conjecture by Mean Curvature Flow	Brendan Guilfoyle	submitted
Kotschick	Dieter	Groups nor presentable by products	C. Loeh	submitted
Lekili	Yanki	Milnor contact structures are universally tight	Burak Ozbagci	submitted
Leykin	Anton	Numerical Algebraic Geometry for Macaulay2		submitted
Liu	Chiu-Chu	Orientability in Yang-Mills theory over nonorientable surfaces	Nan-Kuo Ho, Daniel A. Ramras	submitted
Liu	Chiu-Chu	The Nekrasov conjecture for toric surfaces	Elizabeth Gasparim	submitted
Mark	Thomas	Rational Blowdowns and Monodromy Substitutions	HIsaaki Endo, Jeremy Van Horn-Morris	submitted
Maydanskiy	Maksim	Exotic symplectic manifolds from Lefschetz fibrations		submitted
McDuff	Dusa	The topology of symplectic toric manifolds	none	submitted
Montgomery	Richard	Curve Singularities and Monster/Semple Towers	Alex Castro	submitted
Musiker	Gregg	Linear systems on tropical curves	Christian Haase and Josephine Yu	submitted
Nill	Benjamin	Few smooth d-polytopes with N lattice points	Christian Haase (MSRI member) et.al.	submitted
Nill	Benjamin	xamples of Kaehler-Einstein toric Fano manifolds associated to non-symmetric reflexive polytopes	Andreas Paffenholz (FU Berlin)	submitted
Ozbagci	Burak	Milnor open books of links of some rational surface singularities	Mohan Bhupal	submitted
Ozbagci	Burak	On the Heegaard genus of contact 3-manifolds		submitted
Parker	Brett	Holomorhpic curves in exploded manifolds: compactness		submitted
Parker	Brett	Introduction to exploded manifolds		submitted
Passare	Mikael	A new type of multiplier sequence and discriminant amoebas	Maurice Rojas, Boris Shapiro	submitted
Passare	Mikael	Discriminant coamoebas in dimension two	Lisa Nilsson	submitted

Ratiu	Tudor	Exact gep,etric theory of dendronized polymer dynamics	F. Gay-Balmaz, D. Holm. V. Putkaradze	submitted
Ratiu	Tudor	Symmetry reduced dynamics of charged molecular strands	D. Ellis, F. Gay-Balmaz, D.D. Holm, V. Putkaradze	submitted
Roberts	Lawrence	Some bounds for the knot Floer τ-invariant of satellite knots.		submitted
Sabloff	Joshua	Product structures for Legendrian contact homology	John Etnyre et al.	submitted
Stapledon	Alan	Arc spaces and equivariant cohomology	Dave Anderson	submitted
Stipsicz	András	Combinatorial Heegaard Floer homology and nice Heegaard diagrams	P. Ozsvath, Z. Szabo	submitted
Stipsicz	András	Heegaard Floer homology and nice diagrams	Z. Szabo and P. Ozsvath	submitted
Sturmfels	Bernd	On the convex hull of a space curve	Kristian Ranestad	submitted
Sturmfels	Bernd	Orbitopes	Raman Sanyal and Frank Sottile	submitted
Teichner	Peter	DIfferential forms and 0-dimensional super symmetric field theories	Henning Hohnhold and Stephan Stolz	submitted
Van Horn-Morris	Jeremy	Monodromy Substitutions and Rational Blowdowns	Hasaaki Endo, Tom Mark	submitted
Viro	Oleg	On the main notions of tropical geometry		submitted
Vogel	Thomas	Rigidity versus flexibility for tight Confoliations		submitted
Weber	Joachim	The heat flow and the homology of the loop space		submitted
Williams	Lauren	Tableaux combinatorics for the asymmetric exclusion process and Askey-Wilson polynomials	Sylvie Corteel	submitted
Yu	Josephine	Implicitization Challenge for Binary Factor Analysis	Cueto	submitted
Zvonkine	Dimitri	A group action on Losev-Manin cohomological field theories	Sergey Shadrin	submitted
Buhovski	Lev	Uniqueness of generating Hamiltonians for continuous Hamiltonian flows	Sobhan Seyfaddini	distributable
Eftekhary	Eaman	Knots in homology spheres which have simple knot Floer homology are trivial		distributable
Golovko	Roman	The embedded contact homology of sutured solid tori I		distributable
Herold	Matthias	Tropical orbit spaces and the moduli spaces of elliptic tropical curves		distributable
Hind	Richard	Hamiltonian displacement of a bidisk in a cylinder		distributable
Hutchings	Michael	Proof of the Arnold chord conjecture in three dimensions I	Cliff Taubes	distributable
Hutchings	Michael	Quantitative embedded contact homology		distributable
Izhakian	Zur	Layered supertropical domains	Manfred Knebusch and Louis Rowen	distributable
Jensen	Anders	The 4x4 minors of a 5xn matrix are a tropical basis	Elena Rubei, Melody Chan	distributable
Juhasz	Andras	Cobordisms of sutured manifolds		distributable

Lekili	Yanki	Geometric composition in quilted Floer theory	Max Lipyanskiy	distributable
Lipshitz	Robert	Bimodules in bordered Heegaard Floer homology	Peter Ozsvath, Dylan Thurston	distributable
Lipshitz	Robert	Heegaard Floer homology as morphism spaces	Peter Ozsvath, Dylan Thurston	distributable
Liu	Chiu-Chu	Anti-perfect Morse stratification	Nan-Kuo Ho	distributable
Maclagan	Diane	Introduction to tropical geometry	Bernd Sturmfels	distributable
Mandini	Alessia	The Duistermaat-Heckman formula and the cohomology of moduli spaces of polygons		distributable
Manon	Christopher	The Algebra of Conformal Blocks		distributable
Matic	Gordana	Contact Structures, Sutured Floer homology and TQFT	Ko Honda, WIll Kazez	distributable
Ma'u	Sikimeti	Gluing pseudoholomorphic quilted disks		distributable
Maydanskiy	Maksim	Legendrian surgery formula and P. Seidel's conjecture	Sheel Ganatra	distributable
McMullen	Curtis	Winning sets, quasiconformal maps and DIophantine approximation		distributable
Ozbagci	Burak	Milnor fillable contact structures are universally tight	Yank Lekili	distributable
Parker	Brett	DeRham theory of exploded manifolds		distributable
Rezazadegan	Reza	Pseudoholomorphic quilts and Khovanov homology		distributable
Seidel	Paul	Localization for involutions in Floer cohomology	Ivan Smith	distributable
Severs	Christopher	Pentagonal Relations in the Type-A Cluster Algebra	Helene Barcelo, Jacob White	distributable
Shustin	Eugenii	Tropical curves with one singularity at a fixed point	H. Markwig, T. Markwig	distributable
Thurston	Dylan	Characterizing the universal rigidity of generic frameworks	Steven Gortler	distributable
Weber	Joachim	Transversality for the heat flow		distributable
Yu	Josephine	On a parameterization of positive semidefinite matrices with zeroes	Drton	distributable

2.8 Program Publication Work-In-Progress List

Last Name	First Name	Publication Title	Co-authors	Status
Abouzaid	Mohammed	A geometric criterion for generating the Fukaya category		notes
Ardila	Federico	Hurwitz numbers and De Concini-Procesi-Vergne remarkable spaces		notes
Ardila	Federico	Tropical homogeneous spaces and Coxeter matroid subdivisions	F. Rincon, M. Velasco	notes
Baldridge	Scott	Hypertransverse Knots	Sonja Hohloch	notes
Baldwin	John	An invariant of Legendrian tangles	John Etnyre, Vera Vertesi	notes
Baldwin	John	An invariant of tangles in sutured Floer homology	John Etnyre, Vera Vertesi	notes

Baldwin	John	Transverse link invariants in HFK and HOMFLY homology		notes
Baykur	Refik Inanc	Families of 4-manifolds with nontrivial stable cohomotopy SW invariants	Masashi Ishida	notes
Baykur	Refik Inanc	Round handles, logarithmic transforms and smooth 4-manifolds	Nathan Sunukjian	notes
Berkovich	Vladimir	Algebraic and analytic geometry over the field of one element		notes
Bogart	Tristram	A local obstruction to relative tropical lifting	Eric Katz	notes
Bogart	Tristram	A tropical approach to rational curves on hypersurfaces	Erwan Brugalle, Ethan Cotterill	notes
Buse	Olguta	New constructions of symplectic polydiscs embedings into balls	David Gay	notes
Buse	Olguta	On generalized Hirtzebruck surfaces		notes
Caprau	Carmen	On the quantum filtration of the universal sl(2) foam cohomology		notes
Cautis	Sabin	Coherent sheaves on quiver varieties and categorification	Joel Kamnitzer and Anthony Licata	notes
Cieliebak	Kai	First steps in stable Hamiltonian topology	E.Volkov	notes
Cieliebak	Kai	Symplectic homology, contact homology, and the Eilenberg-Steenrod axioms	A.Oancea	notes
Cornea	Octav	Obstructions to Embedded Lagrangian Cobordism	Paul Biran	notes
Cotton-Clay	Andrew	Untitled	Michael Hutchings	notes
Cruickshank	James	Series Parallel Linkages	Jonathan McLaughlin	notes
Devadoss	Satyan	Deformations of bordered Riemann surfaces and convex polytopes	Tim Heath, Cid Vipismakul	notes
Devadoss	Satyan	Tiling and compactifications using weighted particles	Colin Carroll	notes
Dickenstein	Alicia	A complete combinatorial characterizations of smooth lattice polytopes with high codegree	Benjamin Nill	notes
Dickenstein	Alicia	A naive approach to the implicitization of rational varieties using tropical tools	Bernard Mourrain (INRIA Sophia Antipolis)	notes
Dickenstein	Alicia	Nilsson solutions for irregular a-hypergeometric systems	Laura F. Matusevich and Federico N. Martinez	notes
Dickenstein	Alicia	On the number of positive steady states of sequential multiple phosporilations	Carsten Conradi, Mercedes P'erez Millan, Anne Shiu	notes
Dickenstein	Alicia	Singular points of tropical hypersurfaces	Luis F. Tabera	notes
Dickenstein	Alicia	Steady-state invariants of biochemical reaction networks	Jeremy Gunawardena, Tathagata Dasgupta, Robert Karp, Mercedes Pérez Millan	notes
Draisma	Jan	Infinite Segre powers, their secants, and the substitution monoid	unknown yet	notes
Draisma	Jan	On Luo's rank-determining sets	unknown yet	notes

Draisma	Jan	The tropical projective linear group	Bart Frenk	notes
Eftekhary	Eaman	Knots which admit a surgery with simple knot Floer homology		notes
Eliashberg	Yakov	Symplectic quai-states on the quadric surface	Polterovich	notes
Fabert	Oliver	Topological recursion relations in symplectic field theory	Paolo Rossi	notes
Feichtner	Eva	A tropical approach to resonance in hyperplane arrangements	Mike Falk	notes
Feichtner	Eva	On tropical compactifications of hyperplane arrangements		notes
Feichtner-Kozlov	Dmitry	Stellar equipartitions		notes
Fraser	Maia	N/A	Emmanuel Giroux	notes
Fukaya	Kenji	Floer theory and Mirror symmetry on toric manifolds	Oh, Ohta, Ono	notes
Gadbled	Agnès	On the constructions of exotic tori in projective spaces and products of spheres		notes
Gathmann	Andreas	computation of tropical gravitational descendants with floor diagrams	Hannah Markwig, Florian Block	notes
Gathmann	Andreas	construction of moduli spaces of tropical curves in tropical varieties	Hannah Markwig, Dennis Ochse	notes
Gathmann	Andreas	Independence of Welschinger invariants of the position of the points	Hannah Markwig, Franziska Schroeter	notes
Gathmann	Andreas	study of the locus of points in non-general position for tropical enumerative problems	Franziska Schroeter	notes
Gaubert	Stephane	Tropical polyhedra are equivalent to mean payoff games	Marianne Akian, Alexander Guterman	notes
Gay	David	Convex neighborhood systems and Lefschetz fibrations	Tom Mark	notes
Gay	David	Symplectic polydisk embeddings from Lefscehtz fibrations	Olguta Buse	notes
Georgieva	Penka	Open Gromov Witten invariants		notes
Gerstenberger	Andreas	PhD-thesis, no definite title yet	Kai Cieliebak (advisor)	notes
Ghiggini	Paolo	Embedded contact homology and open book decompositions	Vincent Colin, Ko Honda	notes
Ghiggini	Paolo	The equivalence of Heegaard Floer homology and embedded contact homology via open book decompositions	Vincent Colin, Ko Honda	notes
Ginzburg	Viktor	Leafwise Intersections of Coisotropic Submanifolds	Basak Gurel	notes
Golovko	Roman	Polyfold User's Guide I	Oliver Fabert, Joel Fish, Katrin Wehrheim	notes
Golovko	Roman	The cylindrical contact homology of sutured solid tori		notes
Grigsby	Julia	Bypass Exact Sequence on Sutured Khovanov homology	Stephan M. Wehrli	notes
Grigsby	Julia	On Khovanov-Seidel Quiver Algebras and Bordered Floer homology	Stephan M. Wehrli	notes

Gross	Mark	Log Gromov-Witten invariants	Bernd Siebert	notes
Guilfoyle	Brendan	On the zeros of holomorphic polynomials	Wilhelm Klingenberg	notes
Gurel	Basak	Fragility of leafwise intersections		notes
Harada	Megumi	Examples of Newton-Okounkov bodies in Schubert calculus		notes
Harada	Megumi	GKM descriptions of Mirkovic-Vilonen classes in equivariant cohomology		notes
Harvey	Shelly	Combinatorial Graph Floer Homology	Danielle O'Donnol	notes
Hedden	Matthew	A surface invariant from link Floer homology	Michael Sullivan	notes
Hedden	Matthew	Knot theory of algebraic curves in Stein domains	Burglind Joricke	notes
Herold	Matthias	Moduli spaces of tropical curves of higher genus		notes
Hind	Richard	Symplectic embeddings of bidisks	Samuel Lisi	notes
Hind	Richard	Symplectomorphism groups of domains with contact type boundary	Martin Pinsonnault	notes
Hohloch	Sonja	Hyperkaehler Floer homology as infinite dimensional Hamiltonian system on the loop space	Gregor Noetzel	notes
Hohloch	Sonja	Morse theory and n-categories	Gregor Noetzel	notes
Holm	Tara	Equivariant cohomology for Hamiltonian torus actions on symplectic orbifolds	Tomoo Matsumura	notes
Holm	Tara	Simple Hamiltonian manifolds	Jean-Claude Hausmann	notes
Horn	Peter	Knot concordance filtrations	Tim Cochran, Shelly Harvey, Constance Leidy	notes
Horn	Peter	Non-commutative low dimensional topology	Constance Leidy	notes
Horn	Peter	Phenomena in knot floer homology	David Vela-Vick	notes
Ionel	Eleny-Nicoleta	A geom description of the Virtual Fundamental Cycle (working title)	Thomas Parker	notes
Itenberg	Ilia	Welschinger invariants of small non-toric Del Pezzo surfaces	V. Kharlamov, E. Shustin	notes
Jöricke	Burglind	Analytic knots, satellites and 4-ball genus		notes
Katz	Eric	A Local Obstruction to Lifting Tropical Curves in Hypersurfaces	Tristram Bogart	notes
Katz	Eric	Divisors on Two-dimensional Polyhedral Complexes	Alan Stapledon, Gregg Musiker, Christian Haase	notes
Katzarkov	Ludmil	HMS and Birational Geometry	D. Auroux	notes
Katzarkov	Ludmil	HMS for Manifolds of General type	M. Gross	notes
Kerman	Ely	Lagrangian recurrence	Viktor L. Ginzburg	notes
Kerman	Ely	Obstructions to the symplectic embedding of Lagrangian tori	Richard Hind	notes
Kharlamov	Viatcheslav	Real Cubics in the Third Millennium	Sergey Finashin	notes
Khesin	Boris	A universal variational principle for Burgers-type equations	K. Khanin	notes
Klingenberg	Wilhelm	Zeros of holomorphic polynomials in the unit disk	Brendan Guilfoyle	notes
Kotschick	Dieter	Contact pairs and locally conformally symplectic structures	G. Bande	notes
Kotschick	Dieter	Engel structures and weakly hyperbolic flows on four-manifolds	T. Vogel	notes

Krasner	Daniel	Patterns in sl(2)-link homology	Andrew Lobb	notes
Kutluhan	Cagatay	To be decided	Tolga Etgu and Bulent Tosun	notes
Latschev	Janko	Symplectic field theory and String topology	Kai Cieliebak	notes
Lekili	Yanki	Lagrangian correspondences and three-manifold invariants	Tim Perutz	notes
Licata	Joan	Contact homology for Legendrian tangles		notes
Licata	Joan	Heegaard Floer homology for torus links (tentative)	Jen Hom	notes
Lipshitz	Robert	Relative Q-gradings from Bordered Heegaard Floer Homology	Peter Ozsvath, Dylan Thurston	notes
Lisca	Paolo	Contact surgery an transverse invariants	Andras Stipsicz	notes
Lopez de Medrano	Lucia	Tropical inflection points of plain tropical curves	Erwan Brugalle	notes
Manolescu	Ciprian	Heegaard Floer homology and integer surgeries on links	Peter Ozsvath	notes
Markwig	Hannah	Counting descendant Gromov-Witten invariants with floor diagrams	Florian Block	notes
Markwig	Hannah	Moduli spaces of tropical curves to a line	Andreas Gathmann	notes
Markwig	Hannah	Tropical curves on Hirzebruch surfaces	Erwan Brugalle	notes
McDuff	Dusa	Polytopes with Mass linear functions II: the 4-dimensional case	Sue Tolman	notes
McDuff	Dusa	The virtual moduli space revisited	Wehrheim	notes
McLean	Mark	A Spectral Sequence for Symplectic Homology		notes
McLean	Mark	The Growth Rate of Symplectic Homology		notes
McMullen	Curtis	K3 surfaces automorphisms of small entropy		notes
Melvin	Paul	Pontryagin invariants and integral formulas for Milnor's triple linking number	Dennis DeTurck, Herman Gluck, Rafal Komendarczyk, Clay Shonkwiler, Shea Vela-Vick	notes
Melvin	Paul	Stable isotopy of spheres in 4-manifolds	David Auckly and Daniel Ruberman	notes
Montgomery	Richard	The Generic fiber for the Monster Tower for the Nash-Semple blow up of Surface Singularities	Mikhail Zhitomirskii	notes
Mrowka	Tomasz	The connected sum theorem for monopole floer homology	Ozsvath and Bloom	notes
Musiker	Gregg	Chip-firing on simplicial complexes	Christian Haase, Eric Katz, and Alan Stapledon	notes
Musiker	Gregg	Cluster algebras of Surfaces II	Ralf Schiffler and Lauren Williams	notes
Musiker	Gregg	Description of linear inequivalent classes of certain ranks, degrees, and geni	Ethan Cotterill	notes
Musiker	Gregg	Zonotopes and reduced divisors	Federico Ardila and Ilia Zharkov	notes
Nill	Benjamin	A simple criterion for a projective toric manifold to have dual defect	Alicia Dickenstein (Buenos Aires, MSRI member)	notes

Nill	Benjamin	Polyhedral adjunction theory	Sandra Di Rocco and Christian Haase	notes
Nilsson	Lisa	Coamoebas of Grassmannians	Felipe Rincon	notes
Nilsson	Lisa	Discriminant coamoebas	Elizabeth Wulcan	notes
Nisse	Mounir	Amoebas and Coamoebas of complex linear spaces	Petter Johansson and Mikael Passare	notes
Ozsváth	Peter	Heegaard Floer homology as morphism spaces II	Robert Lipshitz and Dylan Thurston	notes
Passare	Mikael	Mellin transforms of multivariate rational functions	Lisa Nilsson	notes
Pinsonnault	Martin	Counting Hamiltonian Actions	Yael Karshon and Liat Kessler	notes
Pinsonnault	Martin	Symplectic Packings of Rational Ruled manifolds.	Olguta Buse	notes
Pinsonnault	Martin	The homotopy lie algebra of symplectomorphism of non-minimal rational ruled surfaces	Silvia Anjos	notes
Plamenevskaya	Olga	Heegaard Floer contact invariants and rational open books	Matthew Hedden	notes
Polterovich	Leonid	Poisson brackets and symplectic invariants	M.Entov, L.Buhovsky	notes
Rasmussen	Jacob	Low Genus knots in lens spaces		notes
Ratiu	Tudor	Dirac bundle reduction for mechanical systems with symmetry	Hernan Cendra, Jerrold Marsden, Hiroaki Yoshimura	notes
Ratiu	Tudor	Dirac Reduction	H. Cendra, J. Marsden, H. Yoshimura	notes
Ratiu	Tudor	Geodesics on the universal Techmuller space	F. Gay-Balmaz, J.E. Marsden	notes
Ratiu	Tudor	Optimal Dirac Reduction	Madeliene Jotz	notes
Ratiu	Tudor	Representations in continuum mechanics	F. Gay-Balmaz, J. Marsden	notes
Ratiu	Tudor	Symplectic actions with fixed points	A. Pelayo	notes
Ratiu	Tudor	The rigid body dynamics on SO(4)	Petre Birtea, Ioan Casu, Murat Turhan	notes
Risler	Jean-Jacques	Coamoebas and Curvature	M. Passare	notes
Risler	Jean-Jacques	Not yet Chosen	Mikael Passare	notes
Roberts	Rachel	TBA	Sergio Fenley	notes
Rojkovskaia	Natalia	Combinatorial formula for sklyanin determinant in the reflection algebra		notes
Rossi	Paolo	Integrable Systems in Symplectic Topology		notes
Sabloff	Joshua	Higher homotopy groups of the space of Legendrian knots	Mike Sullivan	notes
Sabloff	Joshua	Legendrian contact homology in Seifert fibered spaces	Joan Licata	notes
Sabloff	Joshua	Legendrian knot invariants from knots in the complement	John Etnyre	notes
Sarkar	Sucharit	A construction of knot Floer homotopy		notes

Sarkar	Sucharit	Murasugi sums	Matt Hedden	notes
Sazdanovic	Radmila	Categorification of orthogonal polynomials	Mikhail Khovanov	notes
Sazdanovic	Radmila	categorification of the polynomial ring	Mikhail Khovanov	notes
Sazdanovic	Radmila	Torsion in Khovanov homology of semi-adequate links	Jozef H. Przytycki	notes
Schroeter	Franziska	About divisors and irreducibility in tropical M_{0,n} (preliminary)	Andreas Gathmann	notes
Severs	Christopher	The Homology of the Big Block Partition Lattice	John Shareshian	notes
Shustin	Eugenii	Canonical subvarieties of tropical varieties	H. Markwig, T. Markwig	notes
Shustin	Eugenii	Tropical characteristic classes	H. Markwig, T. Markwig	notes
Shustin	Eugenii	Tropical hypersurfaces with a singularity at a fixed point	H. Markwig, T. Markwig	notes
Shustin	Eugenii	Tropical surfaces with a fixed singularity	H. Markwig, T. Markwig	notes
Siebert	Bernd	A tropical view on Landau Ginzburg models	Michael Carl, Max Pumperla	notes
Siebert	Bernd	Logarithmic Gromov-Witten invariants	Mark Gross	notes
Smith	Ivan	Floer cohomology for pencils of quadrics		notes
Stapledon	Alan	Limiting Hodge numbers via tropical geometry	Eric Katz	notes
Stapledon	Alan	Star-shaped complexes and Ehrhart theory in low dimension	Matthias Beck, Christian Haase	notes
Steingrimsson	Einar	Coloring complexes and the chromatic polynomial	H. Barcelo, M. Kubitzke	notes
Stroppel	Catharina	Integral 6j-symbols and categorification	Josh Sussan, Igor Frenkel	notes
Tabera	Luis	Tropical singular hypersurfaces	Alicia Dickenstein	notes
Teichner	Peter	Geometric filtrations for link concordance	Jim Conant and Rob Schneiderman	notes
Tosun	Bulent	Legendrian non-loose knots	Sinem Celik Onaran	notes
Tsai	Chung-Jun	asymptotic spectral flow on contact three-manifolds		notes
Van Horn-Morris	Jeremy	On symplectic fillings of plumbed open books decompositions	Chris Wendl, Sam Lisi	notes
Vela-Vick	David	Heegaard Floer homology and contact structure on open 3-manifolds	John Etnyre, Rumen Zarev	notes
Vela-Vick	David	Heegaard Floer homology and infinite cyclic covers	Jen Hom	notes
Vela-Vick	David	Heegaard Floer homology and the Alexander module	Peter Horn	notes
Vertesi	Vera	Legndrian and Transverse Satelites and Positive Braids	John Etnyre, Lenny Ng	notes
Vogel	Thomas	Open books	Peter Teichner	notes
Wehrli	Stephan	A new categorification of the colored Jones polynomial		notes
Werner	Annette	Generalizing tropical convexity	Josephine Yu	notes
Williams	Lauren	Canonical bases for cluster algebras in surfaces	Gregg Musiker	notes
Zarev	Rumen	Heegaard Floer homology and contact geometry		notes
Zarev	Rumen	Legendrian and transverse knots	David Shea Vela-Vick	notes

Zharkov	Ilia	Tropical Jacobians and the Tutte polynomial	Ardila, Musiker	notes
Abouzaid	Mohammed	Formality of the symplectic arc algebra	Ivan Smith	rough/draft
Akian	Marianne	Linear systems of symmetrized tropical equations	S. Gaubert, A. Guterman	rough/draft
Ardila	Federico	Counting curves on toric surfaces	Florian Block	rough/draft
Ardila	Federico	Tropical linearity	David Speyer	rough/draft
Baldridge	Scott	Cube diagrams		rough/draft
Baykur	Refik Inanc	On genus two Lefschetz fibrations		rough/draft
Bertrand	Benoit	Genus 0 and 1 Characteristic numbers of the projective plane	E. Brugalle, G. Mikhalkin	rough/draft
Bertrand	Benoit	tropical Computation of generalization of Hurwitz numbers	E. Brugalle, G. Mikhalkin	rough/draft
Blanchet	Christian	Nodal foams and link homology		rough/draft
Bloom	Jonathan	Thesis (A link surgery spectral sequence in Monopole Floer homology)		rough/draft
Brugalle	Erwan	Enumerative invariants of tropical Hirzebruch surfaces	Hannah Markwig	rough/draft
Brugalle	Erwan	Inflexion points of plane tropical curves	Lucia Lopez de Medrano	rough/draft
Brugalle	Erwan	Realizability of superabundant curves	Grigory Mikhalkin	rough/draft
Brugalle	Erwan	Tropical characteristic numbers of TP^2	Benoit Bertrand, Grigory Mikhalkin	rough/draft
Brugalle	Erwan	Tropical computation of Hurwitz numbers	Benoit Bertrand, Grigory Mikhalkin	rough/draft
Buse	Olguta	Packing capaciities and stability numbers in symplectic ruled surfaces	Martin Pinsonnault	rough/draft
Cautis	Sabin	Heisenberg categorification and Hilbert schemes	Anthony Licata	rough/draft
Cieliebak	Kai	String topology and symplectic field theory	J.Latschev	rough/draft
Cochran	Tim	Higher-order signature cocycles for subgroups of mapping class groups	Shelly Harvey and Peter Horn	rough/draft
Cornea	Octav	Enumerative invariants for monotone Lagrangians	Paul Biran	rough/draft
Cotterill	Ethan	Secant plane divisors on the moduli space of curves		rough/draft
Cotton-Clay	Andrew	In preparation	Michael Hutchings	rough/draft
Cruickshank	James	Amoebas and Polygon Spaces	Mikael Passare	rough/draft
Dickenstein	Alicia	Singular tropical plane curves (preliminary)	Luis F. Tabera	rough/draft
Eftekhary	Eaman	Heegaard Floer homology and degree one maps	Akram Alishahi	rough/draft
Eliashberg	Yakov	Symplectic geometry of Stein manifolds	Cieliebak	rough/draft
Etnyre	John	A bound for the radius of a tight ball in a contact metric 3-manifold	Rafal Komendarczyk, Patrik Massot	rough/draft
Etnyre	John	Knot contact homology	Tobias Ekholm, Lenny Ng and Mike Sullivan	rough/draft
Etnyre	John	Legendrian Braids	Vera Vertesi	rough/draft
Etnyre	John	Transverse contact homology	Tobias Ekholm, Lenny Ng and Mike Sullivan	rough/draft
Fabert	Oliver	Local symplectic field theory		rough/draft

Falk	Michael	Tropical geometry and resonance varieties (provisional title)	Eva-MAria Feichtner	rough/draft
Feichtner	Eva	On the stratification of tropical discriminants by singularity type	Hannah Markwig	rough/draft
Feichtner-Kozlov	Dmitry	Combinatorial stacks	Eric Babson	rough/draft
Feichtner-Kozlov	Dmitry	Sites on posets	Elias Minian	rough/draft
Felshtyn	Alexander	Asymptotic invariant and zeta function in symplectic Floer homology		rough/draft
Finashin	Sergey	Topology of real cubic hypersurfaces	V.Kharlamov	rough/draft
Frenk	Bart	A tropical projective linear group	Jan Draisma	rough/draft
Gaubert	Stephane	External representation of tropical polytopes and minimal set covers	Xavier Allamigeon, Eric Goubault, Ricardo Katz	rough/draft
Gay	David	Existence and uniqueness for indefinte Morse 2-functions	Robion Kirby	rough/draft
Ghiggini	Paolo	Sutures and contact homology II	Vincent Colin, Ko Honda, Michael Hutchings	rough/draft
Gilmore	Allison	An algebraic proof of the invariance of knot Floer homology		rough/draft
Ginzburg	Viktor	The Conley Conjecture for Large N	Basak Gurel	rough/draft
Givental	Alexander	The Virasoro conjecture for toric fibrations	J. Brown, T. Coates, H.-H. Tseng	rough/draft
Goldin	Rebecca	Schubert calculus and Bott Samelson manifolds	Alen Knutson	rough/draft
Greene	Joshua	Alternating links and left-orderability		rough/draft
Greene	Joshua	The lens space realization problem		rough/draft
Gross	Mark	Smoothing surface singularities via mirror symmetry	Paul Hacking, Sean Keel	rough/draft
Gross	Mark	Tropical Geometry and Mirror Symmetry		rough/draft
Harada	Megumi	Equivariant K-theory of based loops in SU(2)	Lisa Jeffrey and Paul Selick	rough/draft
Harada	Megumi	Localization via cobordism and twisted Duistermaat-Heckman measure	Yael Karshon	rough/draft
Harada	Megumi	Poset pinball and module generators for equivariant cohomology	Julianna Tymoczko	rough/draft
Hedden	Matthew	Contact invariants for rational open books	Olga Plamenevskaya	rough/draft
Hedden	Matthew	Instantons, Chern-Simons invariants, and Whitehead doubling	Paul Kirk	rough/draft
Hedden	Matthew	Knot Floer homology and Murasugi sums	Sucharit Sarkar	rough/draft
Herold	Matthias	counting elliptic curves		rough/draft
Hohloch	Sonja	Cube diagrams w.r.t. several contact structures	Scott Baldridge	rough/draft
Hom	Jennifer	Bordered Heegaard Floer homology and the invariant of cables		rough/draft
Hutchings	Michael	Proof of the Arnold chord conjecture in three dimensions II	Cliff Taubes	rough/draft
Ionel	Eleny-Nicoleta	Real, Relative GW invariants (Working Tile)		rough/draft

Itenberg	Ilia	Tropical homology	G. Mikhalkin, I. Zharkov	rough/draft
Izhakian	Zur	Supertropical Matrix Algebra III: Generalized Eigenspaces Supertropical Matrix Algebra III: Generalized Eigenspaces Supertropical Matrix Algebra III: Generalized Eigenspaces	Louis Rowen	rough/draft
Jensen	Anders	Computing fiber polytopes	Josephine Yu	rough/draft
Jensen	Anders	Mixed cells	Anton Leykin	rough/draft
Jöricke	Burglind	Holomorphic discs and locally pseudoconvex envelopes over complex manifolds		rough/draft
Jöricke	Burglind	Symplectic knots and quasipositive braids on boundaries of Stein domains	Matthew Hedden	rough/draft
Karshon	Yael	Classification of Hamiltonian torus actions with two dimensional quotients	Sue Tolman	rough/draft
Karshon	Yael	Convexity package for contact moment maps	River Chiang	rough/draft
Karshon	Yael	Localization through cobordism and polytope decompositions (tentative)	Megumi Harada	rough/draft
Katz	Eric	Hodge Numbers of Families of Varieties	Alan Stapledon	rough/draft
Katz	Eric	Lifting Tropical Curves		rough/draft
Katzarkov	Ludmil	Conic Bundles	Zharkov	rough/draft
Katzarkov	Ludmil	HMS and vanishing cycles	Gross	rough/draft
Katzarkov	Ludmil	Rationality and HMS	Auroux Abouzaid	rough/draft
Kharlamov	Viatcheslav	Topological Properties of Real Plane Algebraic Curves	Oleg Viro	rough/draft
Khovanov	Mikhail	Applications of graphical calculus for categorified sl(2)	Anna Beliakova, Aaron Lauda	rough/draft
Kutluhan	Cagatay	Heegaard Floer homology and Seiberg--Witten Floer homology	Yi-Jen Lee and Clifford Henry Taubes	rough/draft
Latschev	Janko	Algebraic torsion in contact manifolds	Chris Wendl	rough/draft
Latschev	Janko	Homological algebra related to riemann surfaces with boundary	Kai Cieliebak and Kenji Fukaya	rough/draft
Lauda	Aaron	A categorification of the quantum Casimir of sl2	Anna Beliakova, Mikhail Khovanov	rough/draft
Lauda	Aaron	Extended Graphical Calculus for categorified quantum sl2	Mikhail Khovanov, Marko Stostic, Marco, Mackaay	rough/draft
Lee	Yi-Jen	ECH and OS	Taubes, Kutluthan	rough/draft
Licata	Joan	Invariants for Legendrian knots in Seifert Fiber Spaces (tentative)	Josh Sabloff	rough/draft
Lipshitz	Robert	Computing Cobordism Maps with Bordered Floer Homology	Peter Ozsvath, Dylan Thurston	rough/draft
Lobb	Andrew	Shadows and Khovanov homology	Oleg Viro	rough/draft
Lobb	Andrew	Stabilization in Khovanov-Rozansky homology	Daniel Krasner	rough/draft
Maclagan	Diane	Bounds on nef cones	Angela Gibney	rough/draft
Mandini	Alessia	Hyperpolygon spaces and moduli spaces of parabolic Higgs bundles	Leonor Godinho	rough/draft

Manolescu	Ciprian	A rectangular 2-algebra for cornered Floer homology	Christopher Douglas	rough/draft
Manolescu	Ciprian	The nilCoxeter 2-algebra and bordered Floer homology	Christopher Douglas	rough/draft
Manon	Christopher	Cluster Algebra and the Moduli of Tropical Curves		rough/draft
Manon	Christopher	The Cox ring of the moduli of principle bundles on a stable curve		rough/draft
Mathews	Daniel	Non-commutative QFT, sutured TQFT		rough/draft
Mathews	Daniel	On the hyperbolic meaning of the Milnor-Wood inequality		rough/draft
Ma'u	Sikimeti	Bimodules and Lagrangian correspondences		rough/draft
Ma'u	Sikimeti	Quilted strips, graph associahedra and A-infinity n-modules		rough/draft
McLean	Mark	Computability and Stein manifolds.		rough/draft
Melvin	Paul	Cohomotopy theory of 4-manifolds	Rob Kirby and Peter Teichner	rough/draft
Meyer	Henning	Intersection Theory on Compact Tropical Toric Varieties		rough/draft
Mohnke	Klaus	Punctured holomorphic curves and Lagrangian embeddings	Kai Cieliebak	rough/draft
Montgomery	Richard	Brake orbits in the planar three-body problem	Rick Moeckel	rough/draft
Mrowka	Tomasz	Khovanov homology is an unknot detector	Peter Kronheimer	rough/draft
Ng	Lenhard	An L-infinity structure on cyclic Legendrian contact homology		rough/draft
Ng	Lenhard	Combinatorial knot contact homology and transverse knots		rough/draft
Ng	Lenhard	Legendrian homology in the boundary of a subcritical Weinstein 4-manifold	Tobias Ekholm	rough/draft
Ni	Yi	Khovanov module and the detection of unlinks	Matthew Hedden	rough/draft
Nill	Benjamin	Mixed Ehrhart theory	Alan Stapledon, Christian Haase, Raman Sanyal	rough/draft
Nisse	Mounir	Amoebas and Coamoebas of complex curves in C^{1+m}		rough/draft
Nisse	Mounir	Complex and Non-Archimedean Coamoebas	Frank Sottile	rough/draft
Parker	Thomas	A structure theorem for Gromov-Witten invariants of symplectic 3-fold	E. Ionel	rough/draft
Passare	Mikael	On amoebas and coamoebas of linear subspaces	Petter Johansson, Mounir Nisse	rough/draft
Passare	Mikael	On the curvatuire of the real amoeba	Jean-Jacques Risler	rough/draft
Payne	Sam	A tropical proof of the Brill-Noether Theorem	Filip Cools, Jan Draisma, and Elina Robeva	rough/draft
Plamenevskaya	Olga	Heegard Floer invariant for rational open books	Matthew Hedden	rough/draft

Plamenevskaya	Olga	Lefschetz fibrations, Heegaard Floer homology and link surgeries spectral sequence	Thomas Mark	rough/draft
Pushkar	Petya	Morse Theory for manifolds with boundary		rough/draft
Pushkar	Petya	On functions without critical points		rough/draft
Rasmussen	Jacob	Triangle maps in sutured Floer homology		rough/draft
Ratiu	Tudor	fixed points of symplectic actions	Alvaro Pelayo	rough/draft
Ratiu	Tudor	none	A. Pelayo	rough/draft
Rezazadegan	Reza	Bordered Heegaard-Floer homology and Khovanov homology of tangles		rough/draft
Rezazadegan	Reza	On Fukaya categories of Lefschetz-Bott fibrations		rough/draft
Roberts	Lawrence	Spanning Tree Homology		rough/draft
Rojkovskaia	Natalia	Quantum characters for Twisted Yangians	E.Mukhin	rough/draft
Sabloff	Joshua	Lagrangian spanning surfaces of Legendrian Knots via generating families	Lisa Traynor	rough/draft
Savelyev	Yakov	On Gromov K-area		rough/draft
Sazdanovic	Radmila	Categorification of completion rings	Stephan Wehrli	rough/draft
Sazdanovic	Radmila	Relations between algebraic and geometric categorification of the chromatic polynomial		rough/draft
Schoenfeld	Eric	Higher SFT Invariants for Cotangent Bundles of Surfaces		rough/draft
Schroeter	Franziska	TBA on Welschinger Invariants	Hannah Markwig, Andreas Gathmann	rough/draft
Seidel	Paul	Symplectic cohomology and q-intersection numbers	Jake Solomon, possibly Roman Bezrukavnikov	rough/draft
Severs	Christopher	The Homology of Real k-Parabolic Subspace Arrangements	Jacob White	rough/draft
Shareshian	John	A chain complex associated to the lattice of ideals in a ranked poset		rough/draft
Shareshian	John	Ideals in the partiton lattice generated by coatoms of fixed shape.	Chris Severs	rough/draft
Shareshian	John	Intersection of conjugates of the large cell in the flag variety	Eric Babson	rough/draft
Shustin	Eugenii	Recursive formulas for Welschinger invariants of small Del Pezzo surfaces	I. Itenberg, V. Kharlamov	rough/draft
Siebert	Bernd	Tropical lambda_g classes	Christian Haase, Hannah Markwig	rough/draft
Smith	Abraham	Integrability of 2nd order PDEs and GL(2,R) geometry		rough/draft
Smith	Ivan	Formality in symplectic khovanov cohomology (provisional)	Mohammed Abouzaid, Paul Seidel	rough/draft
Stapledon	Alan	Higher-dimensional chip firing	Eric Katz, Christian Haase, Gregg Musiker	rough/draft

Steingrimsson	Einar	Enumerating (2+2)-free posets by indistinguishable elements	M. Dukes, S. Kitaev, J. Remmel	rough/draft
Steingrimsson	Einar	The Möbius function of separable and some other permutations	A. Burstein, V. Jelínek, E. Jelínková	rough/draft
Steingrimsson	Einar	The Möbius function of the consecutive pattern poset	A. Bernini, L. Ferrari	rough/draft
Stipsicz	András	Combinatorial Heegaard Floer homology and nice Heegaard diagrams II	P. Ozsvath, Z. Szabo	rough/draft
Stipsicz	András	Heegaard Floer homology and nice diagrams II	Z. Szabo and P. Ozsvath	rough/draft
Stroppel	Catharina	U(sl2)-categorification: Jones-Wenzl projector, 3j-symbols and fractional Euler characteristics	Josh Sussan, Igor Frenkel	rough/draft
Sturmfels	Bernd	Mustafin varieties	Dustin Cartwritght, Mathias Haebich, Annette Werner	rough/draft
Teichner	Peter	Link invariants via Whitney towers	Jim Conant and Rob Schneiderman	rough/draft
Thurston	Dylan	Computing HF^ by factoring mapping classes	Robert Lipshitz and Peter Ozsvath	rough/draft
Thurston	Dylan	On affine rigidity	Steven Gortler, Craig Gotsman, and Ligang Liu	rough/draft
Thurston	Dylan	Volumes of SL(n) representations and Fock-Goncharov coordinates	Stavros Garoufalidis and Christian Zickert	rough/draft
Tolman	Susan	Classification of tall complexity one spaces	Yael Karshon	rough/draft
Tolman	Susan	Integra Kirwan Surjectivity for Hamiltonian manifolds	Tara Holm	rough/draft
Tosun	Bulent	Legendrian cables of positive torus knots	John Etnyre, Doughlas La Fountain	rough/draft
Tosun	Bulent	On the Legendrian and transverse simplicity of cablings		rough/draft
Vertesi	Vera	A Legendrian Arc Invariant in Sutured Floer Homology	John Baldwin, John Etnyre	rough/draft
Viro	Oleg	Multifields, base fields for tropical geometries		rough/draft
Viterbo	Claude	Mather's theory for non convex Hamiltonians		rough/draft
Watson	Liam	New proofs of certain finte filling results		rough/draft
Watson	Liam	On L-spaces and left-orderable fundamental groups	Steve Boyer and Cameron Gordon	rough/draft
Watson	Liam	Turaev torsion, definite 4-manifolds and quasi-alternating knots	Joshua Greene	rough/draft
Werner	Annette	A tropical view on Bruhat Tits buildings		rough/draft
Zarev	Rumen	Gluing results for sutured Floer homology		rough/draft
Zharkov	Ilia	On tropical Hodge conjecture		rough/draft

Zharkov	Ilia	Tropical pryms and conic bundles	Katzarkov	rough/draft
Zvonkine	Dimitri	An introduction to moduli spaces of curves and its intersection theory		rough/draft
Zvonkine	Dimitri	Universal cohomological expressions for singularities in M_{0,n}(CP^1)	Sergey Lando, Maxim Kazarian	rough/draft

3. Postdoctoral Program

3.1 Description of Activities

The postdoctoral program at MSRI is central to MSRI's mission of continued excellence in mathematics research. The semester-long and year-long programs MSRI organizes and hosts produce the leading research in that field of study. MSRI's postdocs engage with fellow mathematicians from all over the world to develop their interests and contribute to the Science community. During the 2009–10 academic year, MSRI selected 31 postdoctoral scholars with research interests in the programs that MSRI offers. Of those postdocs, 22 were funded by the NSF Core Grant, 4 by the NSF Supplemental Grant, 3 by the NSA Grant, and 2 by the Viterbi Endowment.

There were many more excellent postdoc applicants than we could fund with our NSF Postdoctoral Fellowship (PD) budget line. The program organizers used additional funds from their allocated NSF budget to support an additional 12 members who had earned their PhDs no more than five years ago. Those members were called "Postdoc Research Members" (PD/RMs as opposed to NSF Postdoctoral Fellows) and received a per diem of $2,400 per month. While they were not monetarily compensated at the same level as the NSF Postdoctoral Fellows, they received all other privileges. That is, all Postdocs were assigned a mentor upon their arrival, participated in a weekly Postdoc seminar, and were a vibrant part of the research community. They also had the same logistic privileges (office, library access, bus pass, etc…).

Of the 31 Postdoctoral Fellows at MSRI, 7 (23%) were female, 14 (45%) were a U.S. Citizen or Permanent Resident, and 18 (58%) came from a US institution. The program organizers were extremely satisfied with the Postdoctoral program and believed that it was by all accounts an enormous success. Looking at the Institution Placement list below, one sees that, of the 20 NSF Postdocs who stayed in the U.S., 12 (60%) obtained a research position at a Group I University, 6 at a Group II University, and 2 at a Group M University. Of the postdocs who were not U.S. Citizens or Permanent Residents, most obtained research positions at prestigious institutions, such as The Max Planck Institute, Université de Neuchatel, and Université de Montreal.

Here are additional details on the NSF Postdoctoral Fellows for each program.

Symplectic and Contact Geometry and Topology Program

Buhovski, Lev

Lev received his Ph.D. from Tel Aviv University in 2010 under the supervision of Paul Biran. His dissertation was titled "Topological and Functional Rigidity in Symplectic Topology". During his time at MSRI, Lev worked on the C-symplectic topology, together with Sobhan Seyfaddini. They proved the uniqueness result for generating Hamiltonians for continuous Hamiltonian flows. They have submitted their joint paper to the Journal of Symplectic Geometry. He also collaborated with Michael Entov and Leonid Polterovich on symplectic invariant that comes from the Poisson bracket and symplectic approximation theory. They should have a paper out in the next few months. Finally, he has been working with Yaron Ostrover on bi-invariant Finsler metrics on the group of Hamiltonian diffeomorphisms. They showed that, under a natural geometric assumption, any bi-invariant Finsler metric on the group of Hamiltonian diffeomorphism of a closed symplectic manifold induces the same topology on this group as Hofer's metric. They have submitted their work to Inventiones Mathematica. After his stay at MSRI, Lev accepted a 3-year position of Dickson Instructor at the University of Chicago.

Fabert, Oliver

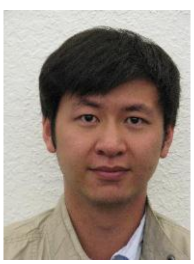
Oliver Fabert received his Ph.D. from the University of Munich (LMU) in 2008 under the supervision of Kai Cieliebak. His dissertation was titled "Transversality results and computations in symplectic field theory" and was written up during his one semester stay at the Swiss Federal Institute of Technology (ETH) in Zurich, Switzerland while joining Dietmar Salamon´s working group. While at MSRI, Oliver continued thinking about the transversality problem for holomorphic curves, mostly together with his mentor Eleny Ionel. He continued to work on the integrable systems structure that naturally appears in symplectic field theory jointly with Paolo Rossi. As a result of this collaboration during his stay at MSRI, they wrote two papers on "String, dilaton and divisor equation in symplectic field theory" (ArXiv preprint 1001.3094) and "Topological recursion relations in non-equivariant cylindrical contact homology" (ArXiv preprint 1007.2287). In both papers, the collaboration at MSRI is highlighted. Together with Joel Fish and Roman Golovko, he organized a working group on Hofer-Wysocki-Zehnder´s polyfold theory which claims to solve the above transversality problem in full generality. See also the survey "Transversality problems in symplectic field theory and a new Fredholm theory" on the Arxiv (1003.0651). Furthermore, he organized a second (of four) working groups exploring the relation between holomorphic curves and integrable systems. Apart from the people he already mentioned, he benefitted very much from discussions with many other great researchers like Yasha Eliashberg, Octav Cornea, and Clifford Taubes. After his stay at MSRI, Oliver accepted a position at The Max Planck Institute for Mathematics in the Sciences.

Gadbled, Agnes

Agnes received her Ph.D. from the Université Louis Pasteur de Strasbourg in 2008. While at MSRI, Agnes described families of monotone symplectic manifolds constructed via the symplectic cutting procedure of Lerman from the cotangent bundle of manifolds endowed with a free circle action. She also gave an obstructions to the monotone Lagrangian embedding of some compact manifolds in these symplectic manifods. The results appeared in the paper "Families of monotone symplectic manifolds constructed via symplectic cut and their Lagrangia sbmanifolds." After her stay at MSRI, Agnes resumed to her postdoctoral position at the Institut de Mathematiques de l'Universite de Neuchatel.

Golovko, Roman

Roman completed his Ph.D. at the University of Southern California in 2009 under the supervision of Ko Honda. His dissertation was titled "The sutured embedded contact homology of S1xD2." While at MSRI, Roman continued thinking about properties and computations of the relative versions of contact homology and embedded contact homology. Some of his computations were submitted for publication. In addition, Roman started a collaboration with Oliver Fabert, Joel Fish, and Katrin Wehrheim working on applications of the theory of polyfolds. This work is in preparation and will be published in a few months. After his stay at MSRI, Roman accepted a 2-year postdoctoral research position at the Universite de Montreal/UQAM.



He, Jian

Jian He received his Ph.D from Stanford University in 2006 under the supervision of Professor Yakov Eliashberg. His dissertation was titled "Symplectic Field Theory of Subcritical Stein Manifolds" In his time at MSRI, Jian continued his work on computing the correlators and descendants of subcritical Stein manifolds. While at MSRI, Jian had many fruitful discussions with Professor Yakov Eliashberg, Kai Cieliebak, Joel Fish and Oliver Fabert, resulting in the preprint "Genus zero correlators of subcritical Stein manifolds". After leaving MSRI, Jian accepted a postdoc position at Université Libre de Bruxelles.

Kutluhan, Cagatay

Cagatay received his Ph.D. from the University of Michigan, Ann Arbor in 2009 under the supervision of Daniel M. Burns, Jr. His dissertation was titled "Floer homology and symplectic forms on S^1 X M^3." While at MSRI, Cagatay continued thinking about generalizations of his thesis result as well as related other problems. He also investigated several constructive methods in contact and symplectic topology and their interplay with gauge theory and Floer homology. He learned a great deal more about the latter through seminars, working groups, and by direct contact with experts in the field. Moreover, he started a project with Tolga Etgu and Bulent Tosun during his stay. However, the most exciting progress in his research took place of the beginning of 2010 when he and his collaborators Yi-Jen Lee and Clifford Henry Taubes finally figured out how to prove the equivalence of Heegaard Floer homology and Seiberg-Witten Floer homology. They have already posted two of the five preprints that prove this equivalence on arXiv in the Summer of 2010. After his stay at MSRI, Cagatay started his position as a Ritt Assistant Professor at Columbia University.

Lekili, Yanki

Lekili received his Ph.D. from MIT in May 2009 under the supervision of Denis Auroux. His dissertation was titled "Broken Lefchetz fibrations, Lagrangian matching invariants and Oxvath-Szabo invariants." The postdoc position that he held at MSRI was his first experience as a researcher after graduate school. Overall, he had an outstanding research/learning experience at MSRI. While at MSRI, he worked on several projects, some of which were initiated and completed at MSRI. As for the latter, he completed two joint papers on open books and contact structures; one of these paper is with Tolga Etgu and the other is with Burak Ozbagci. Both of these papers are now published in IMRN & MRL. Healso completed another preprint with Max Lipyanskiy on quilted Floer homology. Finally, he made significant progress on his joint paper with Tim Perutz, which concerns an extension of Heegaard Floer invariants to three-manifolds with boundary. This latter work is still in progress. As for the learning experience, he felt that he has learned quite a bit from the numerous seminar talks and conferences that he attended while at MSRI. In particular, the seminars organized by Yakov Eliashberg and Paul Seidel were really interesting and pointed toward new research directions he plans to pursue in the future. After his stay at MSRI, he accepted on a position at The Max-Planck Institut in Bonn for the summer period. In the coming years, Lekili will be a junior research fellow at the University of Cambridge.

Ma'u, Sikimeti

Sikimeti received her Ph.D. from Rutgers University in 2008 under the supervision of Christopher Thomas Woodward. Her dissertation was titled "The Multiplihedra in Lagrangian Floer Theory". While at MSRI, Sikimeti worked on analytical and algebraic aspects of Quilted Floer theory. During the Fall 2009, she completed "Gluing Pseudoholomorphic Quilted Disks," and in the Spring of 2010 she completed "Quilted strips, graph associahedra, and A-infinity n-modules and nearly completed "A-infinity bimodules for Lagrangian correspondences." According to Sikimeti, "the biggest benefit [of her membership at MSRI] was the networking aspect, getting to know people who work in the field, being able to talk to them in person. Another benefit was finding out the interesting directions people are moving towards now and getting lots of new ideas for one's own research." After her stay at MSRI, Sikimeti took a postdoctoral fellowship position at Barnard College.

McLean, Mark

Mark received his Ph.D. from the University of Cambridge in 2008. Mark spent his time at MSRI working on two papers on symplectic homology. The first paper "A Spectral sequence for symplectic homology" constructs a spectral sequence converging to symplectic homology of a Lefschetz fibration whose E1 pages are Floer homology groups of the monodromy symplectomorphism of this Leftchetz fibration; this is then used to prove a theorem about fixed points of certain symplectomorphisms. The second paper, "The growth rate of symplectic homology and applications" proved several properties of an invariant of Louiville domains called the growth rate of symplectic homology. Mark used growth rates to show that the unit cotangent bundle of a rational hyperbolic manifold is not Stein fillable by a smooth affine variety. Mark also has a growth rate criterion for infinitely many Reeb orbits and a sketch of a computability result which will be written up in a third paper. After his stay at MSRI, Mark resumed to this previous position as a postdoc at MIT.

Parker, Brett

Brett Parker received his Ph.D. from Stanford in 2005 under the supervision of Yakov Eliashberg. His dissertation was titled "Holomorphic curves in Lagrangian torus fibrations". In his time at MSRI, Brett worked on holomorphic curve theory in a new category called the category of exploded manifolds which has applications to symplectic topology and is related to tropical geometry. Brett's postdoc at MSRI allowed him to explain his approach to tropical geometry to many members of the Tropical Geometry program and to understand connections to Mark Gross and Berndt Siebert's approach to tropical geometry and mirror symmetry using Log geometry. He also understood the connection between the exploded semialgebra, which he works with, and Oleg Viro's multiple valued fields operations. Brett's participation in the symplectic and contact geometry and topology program allowed him to explain to symplectic topologists how exploded manifolds are useful in symplectic topology and to benefit from the collective expertise of the other members of that program that work with holomorphic curves. After his stay at MSRI, Brett took up a postdoctoral research position at the University of Zürich.

Savelyev, Yakov

Yakov received his Ph.D. from SUNY Stony Brook in 2008 under the supervision of Dusa McDuff. While at MSRI, Yakov worked on the paper titled “On Gromov K-Area” and revised a paper titled “Bott periodicity and stable quantum classes”. Both are currently on arxiv. He also presented a well received talk in the research seminar, and also spoke to many people about new ideas. Some of those people include Hutchings, Teleman, Givental, Eliashberg, Bukhosky, Polterovich, and McDuff. After his stay at MSRI, he resumed to his previous position as a postdoc at the University of Massachusetts at Amherst.

Vertesi, Vera

Vera Vertesi received her Ph.D. from Eotvos University in Budapest, Hungary in 2009 under the supervision of Andras Stipsicz.
During her stay at MSRI, she finished a paper about the classification of Legendrian representations of twist knots with J. Etnyre and L. Ng (http://arxiv.org/pdf/1002.2400). She has several ongoing projects initiated at MSRI. With J. Baldwin and J. Etnyre, they defined an invariant in sutured Floer homology for arcs and an element in it for Legendrian arcs. With J. Etnyre and L. Ng they classified transverse representations of some cables of some Legendrian simple types. Vera was working on a Reidemeister-type theorem for contact structures on a surface cross interval obtained by a sequence of bypass attachments. She also started to study the use of bordered Floer homology in understanding the rank of Heegaard Floer homology. After her stay at MSRI, Vera went to Massachusetts Institute of Technology as a CLE Moore Instructor.

Tropical Geometry Program

Bogart, Tristram

Tristam received Ph.D. at the University of Washington in 2007 under the supervision of Rekha R. Thomas. His dissertation was titled "Problems in Computational Algebra and Integer Programming". Before attending MSRI, he had begun a project with Ethan Cotterill on the tropical version of Clemens' theorem on rational curves in hypersurfaces. Erwan Brugalle joined the team on this project during the MSRI semester. Tristram's understanding of the floor diagram approach to tropical curves was greatly increased by talking to Clemen, Florian Block, and Kristen Shaw at MSRI. Tristram also began a related project with Eric Katz, "Obstructions to lifting tropical curves in hypersurfaces." They identified a specific local obstruction for curves inside hypersurfaces in tropical three- or four-space. They can use it to better understand several examples, including one by Magnus Vigeland and one by Diane Maclagan. They are currently writing the paper and plan to submit it to a journal in the next few weeks. After the tropical semester, Tristram returned to Queen's University for his fifth and last semester as a postdoc. In 2010-11, he is an MSRI-funded postdoc at San Francisco State, in the early stages of projects with SFSU faculty Federico Ardila (on the tropical Grassmannian) and Joseph Gubeladze (on the space of affine maps between two fixed polygons, which is itself a polytope.)

Brugalle, Erwan

Erwan received his Ph.D. at the Université de Paris VI in 2004 under the supervision of Ilia Itenberg. His dissertation was titled "Real lgebraic curves and real pseudoholomorphic curves in ruled surfaces".
At MSRI, he collaborated with other members of the Tropical Geometry Program such as Grigory Mikhalkin, Lucia Lopez de Medrano, Hannah Markwig, Ethan Cotterill and Tristram Bogart, Josephine Yu, and Ilia Zharkov. In addition, he established many new contacts that will certainly be fruitful in the near future. He had the opportunity to learn a lot from these new contacts. In conclusion, according to Erwan, his postdoc at MSRI has been very profitable for him: it enlarged his mathematical panorama. He finished ongoing works, started new ones, and made new contacts. He's looking forward for a next stay at MSRI! Erwan currently holds the position of Maître de Conférence at the Jussieu University - Paris 6.

Katz, Eric

Eric received his Ph.D. from Stanford University in 2004 under the supervision of Yakov Eliashberg. His dissertation was titled “A Formalism for Relative Gromov-Witten Invariants”. According to Eric, his semester in the MSRI Tropical Geometry program was very important for his career. He got to know his fellow researchers better and began new collaborations. Specifically, he began work with Alan Stapledon on a joint project that has since produced a preprint, "The Tropical Motivic Nearby Fiber" and with Tristram Bogart on a project whose preprint, "Lifting Tropical Curves in Hypersurfaces" is forthcoming. In addition, he did research relating lifting tropical curves in space and Matt Baker's theory of linear systems on graphs. Following his stay at MSRI, Eric has been working as a postdoc at University of Texas A&M (through Texas's RTG and then as an NSF Institutes Postdoc).

Lopez de Medrano, Lucia

Lucia received her Ph.D. from the Univesité de Paris 7 in 2007 under the supervision of Jean-Jacques Risler. Her dissertation was titled “Total curvature of real algebraic hypersurfaces and patchwork.” While at MSRI Lucia worked with Erwan Brugalle in the tropicalisation of inflection points. This work led to a paper that will be submitted soon. As a result of this work, they gave a positive answer to the existence of real algebraic curves with the maximum number of real inflection points and the maximum number of connected components. She also had very interesting discussions with Mikael Passare about the amiba of a line in the 3 dimensional complex space, which may lead to a joint project. Last but not least, Lucia spent this semester surrounded by people with many mathematical interest in common. For her it was “a unique opportunity.” At the end of the semester, Lucia gave birth in Berkeley to her first son, Mahigan. She is very thankful with all the MSRI staff for their support in one of the most important moments of her personal life. After her stay at MSRI, Lucia took on a postdoctoral position at the Universidad Nacional Autonoma de Mexico (UNAM).

Nill, Benjamin

Benjamin received his Ph.D. at Eberhard Karls Universitaet Tuebingen (Germany) in 2005. His dissertation was titled “Gorenstein toric Fano varieties”. During his time at MSRI, Benjamin continued to work on lattice polytopes and toric geometry and learned about connections to tropical geometry. In a joint project with Alicia Dickenstein a relation between the combinatorial invariant of a smooth lattice polytope and the dual defect of the associated polarized toric manifold could be proven by confirming an adjunction-theoretic conjecture by Beltrametti and Sommese. This work resulted in a publication in Mathematical Research Letters. Discussions with Janko Boehm also renewed Benjamin's interest in combinatorial aspects of mirror symmetry and led to a collaboration with Jan Schepers on stringy E-functions of Gorenstein polytopes. The preprint has been submitted. After leaving MSRI, Benjamin accepted a two-year position as a postdoctoral associate and part-time instructor at the University of Georgia.

Nisse, Mounir

Mounir received his Ph.D. from Unversite Pierre et Marie-Curie – Paris 6 in 2009 under the supervision of Jean-Jacquest Risler. His dissertation was titled "On the geometry and the topology of amoebas and coamoebas of complex Algebraic varieties." While at MSRI, Mounir worked on these objects with Petter Johansson and Mikael Passre, and they gave a complete description of them in the case of complex linear spaces. It is his first preprint in MSRI titled "(Co) amoebas of complex linear spaces". He also worked with Frank Sottile at Texas A&M University. They defined a new object (the analogous of the logarithmic limit set) for any algebraic variety which they call *Phase limit set*, and they proved some analogous combinatorial properties of this object similar to that of the logarithmic limit set. It is his second preprint titled "Complex and non-Archimedean Coameobas". After his stay at MSRI, Mounir went to Paris 6 for one semester, and now he is a Vistiting Assitant Professor at Texas A&M University in College Station.

Stapledon, Alan

Alan received his Ph.D. from the University of Michigan in 2009 under the supervision of Mircea Mustata. His dissertation was titled "The Geometry and Combinatorics of Ehrhart h*-Vectors". While at MSRI, Alan spent time learning about tropical geometry and exploring connections with Hodge theory. Alan and a fellow MSRI postdoc, Eric Katz, introduced a new invariant associated to tropical varieties called the "tropical motivic nearby fiber", which appears in a recently submitted paper. Alan also spent time working with Benjamin Nill on several topics in Ehrhart theory, and Gregg Musiker and Christian Haase on chip-firing in higher dimensions. After his stay at MSRI, Alan began a postdoc at the University of British Columbia.

Williams, Lauren

Lauren received her Ph.D. from Massachusetts Institute of Technology in 2005 under the supervision of Richard Peter Stanley. Her dissertation was titled "Combinatorial Aspects of Total Positivity." While at MSRI, Lauren continued thinking about total positivity and its connections to tropical geometry. She also investigated the connections between Teichmuller theory and tropical geometry via cluster algebras associated to surfaces. But probably the most beneficial aspects of her postdoc at MSRI, according to Lauren, was establishing new contacts. She had several very interesting discussions with Mark Gross about mirror symmetry and possible connections to cluster algebras. She also met several time with her mentor Grisha Mikhalkin who explained to her the Thurston compactification of Teichmuller space. In addition, she met Rick Kenyon and had several very interesting discussions with him, which may lead to a joint project. After her stay at MSRI, Lauren took on a position of assistant professor at the University of California, Berkeley.

Homology Theories of Knots and Links Program

Grigsby, Elisenda

Elisenda Grigsby received her Ph.D. from UC Berkeley in 2006 under the supervision of Robion Kirby and Peter Ozsvath. Her dissertation was titled, "Knot Floer homology in Cyclic Branched Covers". While at MSRI Elisenda investigated the connections between Khovanov homology and Heegaard Floer homology, with a focus on developing a concrete algebraic relationship between modules over certain quiver algebras described by Khovanov-Seidel and the bordered Floer homology package of Lipshitz-Ozsvath-Thurston. Being at MSRI during this period allowed her easy access to many of the experts in both fields some of whom she had not spoken with prior to her time at MSRI. In particular, conversations with Denis Auroux, Stephan Wehrli, Tony Licata, Robert Lipshitz, Peter Ozsvath, and Catharina Stroppel were extremely useful in the development of this project. She is currently writing up her results in collaboration with Auroux (a new collaborator) and Wehrli (a long-time collaborator). In addition to this, she continued many other useful conversations with John Baldwin, Matthew Hedden, Jen Hom, Adam Levine, Joan Licata, Lawrence Roberts, and Liam Watson on various aspects of Heegaard-Floer homology and low-dimensional topology. She found the bordered Floer homology working group (organized by Matt Hedden) extremely helpful, especially since it encouraged her to work through some important examples with Allison Gilmore, Jen Hom, Joan Licata, and Stephan Wehrli. In the fall of 2009 (a semester prior to her arrival at MSRI) Elisenda began a position as a tenure-track assistant professor at Boston College, where she has now returned.

Kutluhan, Cagatay

Cagatay received his PhD from the University of Michigan, Ann Arbor in 2009 under the supervision of Daniel M. Burns, Jr. His dissertation was titled "Floer homology and symplectic forms on S^1 X M^3". While at MSRI, Cagatay continued thinking about generalizations of his thesis result as well as related other problems. He also investigated several constructive methods in contact and symplectic topology and their interplay with gauge theory and Floer homology. He learned a great deal more about the latter through seminars, working groups and by direct contact with experts in the field. Moreover, he started a project with Tolga Etgu and Bulent Tosun during his stay. However, the most exciting progress in his research took place in the beginning of 2010 when he and his collaborators Yi-Jen Lee and Clifford Henry Taubes finally figured out how to prove the equivalence of Heegaard Floer homology and Seiberg-Witten Floer homology. They have already posted two of the five preprints that prove this equivalence on arXiv in Summer of 2010. After his stay at MSRI, Cagatay started his position as a Ritt Assistant Professor at Columbia University.

Lekili, Yanki

Lekili received his Ph.D. from MIT in May 2009 under the supervision of Denis Auroux. His dissertation was titled "Broken Lefchetz fibrations, Lagrangian matching invariants and Oxvath-Szabo invariants." The postdoc position that he held at MSRI was his first experience as a researcher after graduate school. Overall, he had an outstanding research/learning experience at MSRI. While at MSRI, he worked on several projects, some of which were initiated and completed at MSRI. As for the latter, he completed two joint papers on open books and contact structures; one of these paper is with Tolga Etgu and the other is with Burak Ozbagci. Both of these papers are now published in IMRN & MRL. Healso completed another preprint with Max Lipyanskiy on quilted Floer homology. Finally, he made significant progress on his joint paper with Tim Perutz, which concerns an extension of Heegaard Floer invariants to three-manifolds with boundary. This latter work is still in progress. As for the learning experience, he felt that he has learned quite a bit from the numerous seminar talks and conferences that he attended while at MSRI. In particular, the seminars organized by Yakov Eliashberg and Paul Seidel were really interesting and pointed toward new research directions he plans to pursue in the future. After his stay at MSRI, he accepted on a position at The Max-Planck Institut in Bonn for the summer period. In the coming years, Lekili will be a junior research fellow at the University of Cambridge.

Krasner, Daniel

Daniel received his Ph.D degree from Columbia University in 2009 under the supervision of Mikhail Khovanov. His dissertation was titled "Computations and structures in sl(n)-link homology". During his stay at MSRI, Daniel worked closely with his mentor, Thomas Mark. After his stay at MSRI, Daniel took on the Assistant Adjunct Professor position at UCLA.

Lobb, Andrew

Andrew received his Ph.D. degree from Harvard University in 2007 under the supervision of Peter Benedict Kronheimer. His dissertation was titled "A Slice Genus Lower-Bound from SL(n) Khovanov-Rozansky Homology". During his stay at MSRI, Andrew worked closely with his mentor, Matt Hedden. After his stay at MSRI, Andrew took on a postdoctoral position at SUNY Stony Brook.

Sazdanovic, Radmila

Radmila Sazdanovic received her Ph.D. degree from George Washington University in January 2010 under the supervision of Jozef H. Przytycki. While at MSRI, Radmila expanded her knowledge and continued her dissertation research on Khovanov homology and the categorification of the polynomial ring. Jointly with Mikhail Khovanov, she introduced diagrammatics for categorification of Chebyshev and Hermite polynomials and started a new collaboration with Stephan Wehrli working on categorifications of ring completions. After MSRI, Radmila took the Postdoctoral Researcher position in the Department of Mathematics at the University of Pennsylvania.

Wehrli, Stephan

Stephan received his Ph.D. from the University of Zurich in 2007 under the supervision of Anna Beliakova. His dissertation was titled "Contributionis to Khovanov Homology". During his time at MSRI, Stephan worked closely with his mentor, Associate Director, David Auckly. After his stay at MSRI, he went to a tenture-track position at SUNY Syracuse.

Vertesi, Vera

Vera Vertesi received her Ph.D. from Eotvos University in Budapest, Hungary in 2009 under the supervision of Andras Stipsicz.
During her stay at MSRI, she finished a paper about the classification of Legendrian representations of twist knots with J. Etnyre and L. Ng (http://arxiv.org/pdf/1002.2400). She has several ongoing projects initiated at MSRI. With J. Baldwin and J. Etnyre, they defined an invariant in sutured Floer homology for arcs and an element in it for Legendrian arcs. With J. Etnyre and L. Ng they classified transverse representations of some cables of some Legendrian simple types. Vera was working on a Reidemeister-type theorem for contact structures on a surface cross interval obtained by a sequence of bypass attachments. She also started to study the use of bordered Floer homology in understanding the rank of Heegaard Floer homology. After her stay at MSRI, Vera went to Massachusetts Institute of Technology as a CLE Moore Instructor.

Complementary Program 2009-10

Hillar, Christopher
Fall 2009

Christopher received his Ph.D. from UC Berkeley in 2005 under the supervision of Bernd Sturmfels. His dissertation was titled “Solving Polynomial Systems with Special Structure.” In his time at MSRI Christopher worked on applications of compressed sensing to sparse coding with Fritz Sommer at the Redwood Institute for Theoretical Neuroscience. They have submitted their work to a NIPS conference and will be finishing up a journal article in the next month. He has also been collaborating with Lek-Heng Lim at Berkeley on the computational complexity of tensor decompositions. They should also have a paper out in the next few months. Finally, he has been working with Pentti Kanerva and Fritz Sommer on the mathematics underlying a new computational paradigm, "Hyperdimensional Computing." Through this research, they hope to understand and model complex systems that appear to be turing incompatible. After the fall semester at MSRI, Christopher continues his fellowship as an external postdoc, for the spring semester of 2010, at the Redwood Center for Theoretical Neuroscience (University of California at Berkeley) with his mentor, Fritz Sommer.

Severs, Christopher

Christopher completed his Ph.D. at Arizona State University in 2009 under the supervision of Hélène Barcelo. His dissertation was titled “On the Discrete Fundamental Groups of the Associahedron and Cyclohedron.” During his time at MSRI, Christopher worked on some real subspace arrangements, called k-equal arrangements, with Hélène Barcelo and Jacob White. Their work was accepted for publication in the Transactions of the American Mathematical Society. Further work by Christopher and Jacob White on this subject was accepted for a presentation at the International Conference on Formal Power Series and Algebraic Combinatorics in San Francisco. While at MSRI, Christopher also started a collaboration with John Shareshian of Washington University at St. Louis. This work is in its early stages but has so far yielded results that have applications in computational group theory. After leaving MSRI, Christopher accepted a two-year postdoctoral research position at Reykjavik University in Iceland.

Postdoctoral Fellow Program supported by the NSF Supplemental Grant DMS-0936277

Angeltveit, Vigleik

Vigleik received his Ph.D. from Massachusett Institute of Technology in 2006 under the supervision of Haynes Miller. His dissertation was titled "Noncommutative Ring Spectra." During the 2009-10 academic year, Vigleik spent time trying to understand the algebraic K-theory of some very simple rings. His paper titled "Uniqueness of Morava K-theory" had been accepted for publication, pending revisions, in Compositio Mathematica. Vigleik with Gerhardt also submitted to the Journal of Pure and Applied Algebra a paper titled "RO(S1)-graded TR-groups." And finally, they submitted a paper titled "On the algebraic K-theory of coordinate axes over the intergers" to Mathematical Research Letters. Vigleik continues his external postdoctoral fellowship with MSRI for the 2010-11 academic year at the University of Chicago with his mentor, Peter May.

Crofts, Scott

Scott received his Ph.D. from the University of Utah in 2009 under the supervision of Peter Trapa. His dissertation was titled "Duality for the universal cover of Spin (2n+1,2n)." One of the main things he accomplished during the 2009-10 academic year was generalizing the primary result in his thesis and submitting a paper to the electronic journal Representation Theory. At the same time, he collaborated with Jeffrey Adams at the University of Maryland to develop a two-sided parameter space for nonlinear simply laced groups explanding on the work of Fokko du Cloux. In addition, he collaborated with Peter Trapa to classify the W-cells for nonlinear indefinite unitary groups. Scott continues his external postdoctoral fellowhip with MSRI for the 2010-11 academic year at the Univesrity of California at Santa Cruz with his mentor, Martin Weissman.

Hillar, Christopher
Spring 2010

Christopher received his Ph.D. from UC Berkeley in 2005 under the supervision of Bernd Sturmfels. His dissertation was titled "Solving Polynomial Systems with Special Structure." In his time at MSRI Christopher worked on applications of compressed sensing to sparse coding with Fritz Sommer at the Redwood Institute for Theoretical Neuroscience. They have submitted their work to a NIPS conference and will be finishing up a journal article in the next month. He has also been collaborating with Lek-Heng Lim at Berkeley on the computational complexity of tensor decompositions. They should also have a paper out in the next few months. Finally, he has been working with Pentti Kanerva and Fritz Sommer on the mathematics underlying a new computational paradigm, "Hyperdimensional Computing." Through this research, they hope to understand and model complex systems that appear to be turing incompatible. Christopher continues his external postdoctoral fellowship with MSRI for the 2010-11 academic year at the Redwood Center for Theoretical Neuroscience (University of California at Berkeley) with his mentor, Fritz Sommer.

Mahlburg, Karl

Karl received his Ph.D. from the University of Wisconsin at Madison in 2006 under the supervision of Ken Ono. His dissertation was titled “Congruences for the coefficients of modular forms and applications to number theory.” In collaboration with Kathrin Bringmann, Karl developed a full research program with applications in number theory, combinatorial probability, and statistical mechanics. He additionally established new interests and collaborations within combinatorial probability, notably with Alexander Holroyd and Lionel Levine. On top of many talks he gave throughout the year, Karl and Kathrin completed and submitted a paper titled “Improved bounds on metastability thresholds and probablities for generalized bootstrap percolation.” Karl continues his external postdoctoral fellowship with MSRI for the 2010-11 academic year at Princeton University with his mentor, Manjul Bhargava.

Smith, Abraham

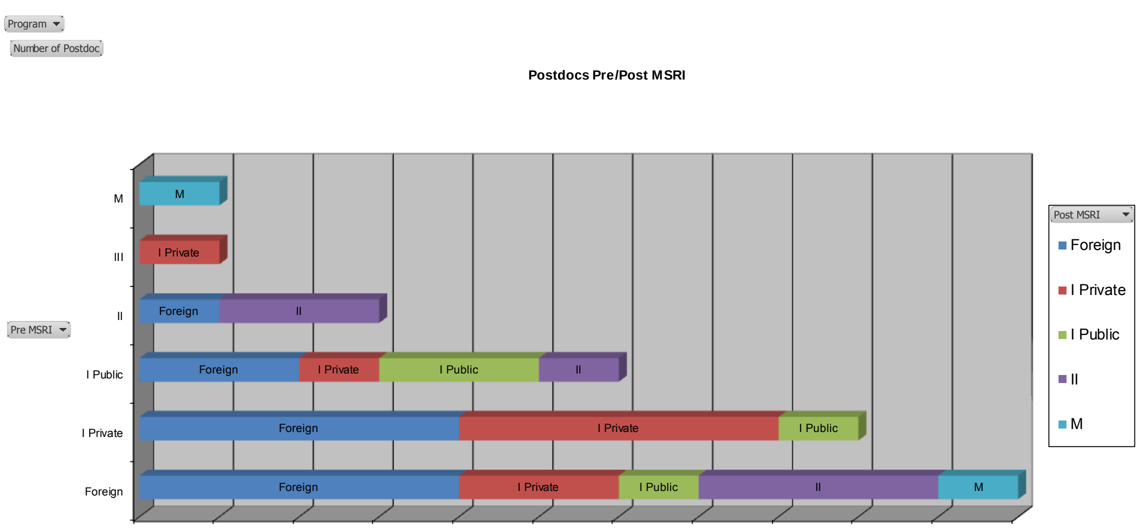
Abraham received his Ph.D. from Duke University in 2009 under the supervision of Robert Bryant. This dissertation was titled “Integrability of Second-Order PDEs and the Geometry of GL (2)-Structures.” During the fall of 2009, Abraham completed a paper titled “Integrable GL (2) Geometry and Hydrodynamic Partial Differential Equations” which was submitted to Communications in Analysis and Geometry. He continued his research on a broad generalization of theory on PEDs in any number of variables. In addition, he participated in numerous seminars throughout the year. Abraham is in the process of organizing a workshop on the geometry of PDEs to be held at CRM in Montreal during summer 2011. He continues his external postdoctoral fellowship with MSRI for the 2010-11 academic year at McGill University in Quebec with his mentor, Niky Karman.

3.2 Postdoctoral Fellow Placement List

Family Name	First Name	Placement Institution	State	Country	Position	MSRI Mentor	Program
Angeltveit	Vigleik	University of Chicago	IL	US	Postdoc	Peter May	Ext. PD 2009-10
Bogart	Tristram	San Francisco State University	CA	US	Postdoc	Federico Ardila	TG
Brugalle	Erwan	Jussieu University - Paris 6		FR	Postdoc	Mikael Passare	TG
Buhovski	Lev	University of Chicago	IL	US	Postdoc	Octav Cornea	SCGT
Crofts	Scott	UC Santa Cruz	CA	US	Postdoc	Martin Weissman	Ext. PD 2009-10
Fabert	Oliver	Max Planck Institute		DE	Researcher	Eleny Ionel	SCGT
Gadbled	Agnès	Universite de Neuchatel		CH	Postdoc	Kai Cieliebak	SCGT
Golovko	Roman	Universite de Montreal		CA	Researcher	Mike Hutchings	SCGT
Grigsby	Julia	Boston College	MA	US	Assistant Professor	Rachel Roberts	HTKL
He	Jian	Universite Libre de Bruxelles		BE	Postdoc	Kai Cieliebak	SCGT
Hillar	Christopher	Redwood Center for Theoretical Neuroscience, UC Berkeley	CA	US	Postdoc	Fritz Sommer	CP 2009-10
Katz	Eric	Texas A&M University	TX	US	Postdoc	Dmitry Feichtner-Kozlov	TG
Krasner	Daniel	UCLA	CA	US	Assistant Professor	Thomas Mark	HTKL
Kutluhan	Cagatay	Columbia University	NY	US	Assistant Professor	Tomasz Mrowka	HTKL
Lekili	Yanki	University of Cambridge		GB	Junior Research Fellow	Ko Honda	HTKL
Lobb	Andrew	SUNY Stony Brook	NY	US	Postdoc	Matt Hedden	HTKL
Lopez de Medrano	Lucia	Universidad Nacional Autonoma de Mexico		MX	Postdoc	Bernd Sturmfels	TG
Mahlburg	Karl	Princeton University	NJ	US	Postdoc	Manjul Bhargava	Ext. PD 2009-10
Ma'u	Sikimeti	Barnard College	NY	US	Postdoc	Denis Auroux	SCGT
McLean	Mark	MIT	MA	US		Lenny Ng	SCGT
Nill	Benjamin	University of Georgia	GA	US	Instructor	Ilia Itenberg	TG
Nisse	Mounir	Texas A&M University	TX	US	Assistant Professor	Andreas Gathmann	TG
Parker	Brett	University of Zurich		CH	Postdoc	Yasha Eliashberg	SCGT
Savelyev	Yakov	University of Massachusetts, Amherst	MA	US	Postdoc	Leonid Polterovich	SCGT
Sazdanovic	Radmila	University of Pennsylvania	PA	US	Postdoc	Dylan Thurston	HTKL
Severs	Christopher	Reykjavik University		IS	Postdoc	Helene Barcelo	CP 2009-10
Smith	Abraham	McGill University		CA	Postdoc	Miky Karman	Ext. PD 2009-10
Stapledon	Alan	University of British Columbia		CA	Postdoc	Viatcheslav Kharlamov	TG
Vertesi	Vera	MIT	MA	US	Instructor	Ko Honda	HTKL
Wehrli	Stephan	Syracuse University	NY	US	Assistant Professor	David Auckly	HTKL
Williams	Lauren	UC Berkeley	CA	US	Assistant Professor	Grisha Mikhalkin	TG

2009-10 Postdocs' Home Institution

(based on AMS Groupings)



Highlights

Of the nine postdocs who came from Group I Private Insitutions, four are currently at Group I Private Institutions. The others are divided among Group I Public Institutions and Foreign Institutions.

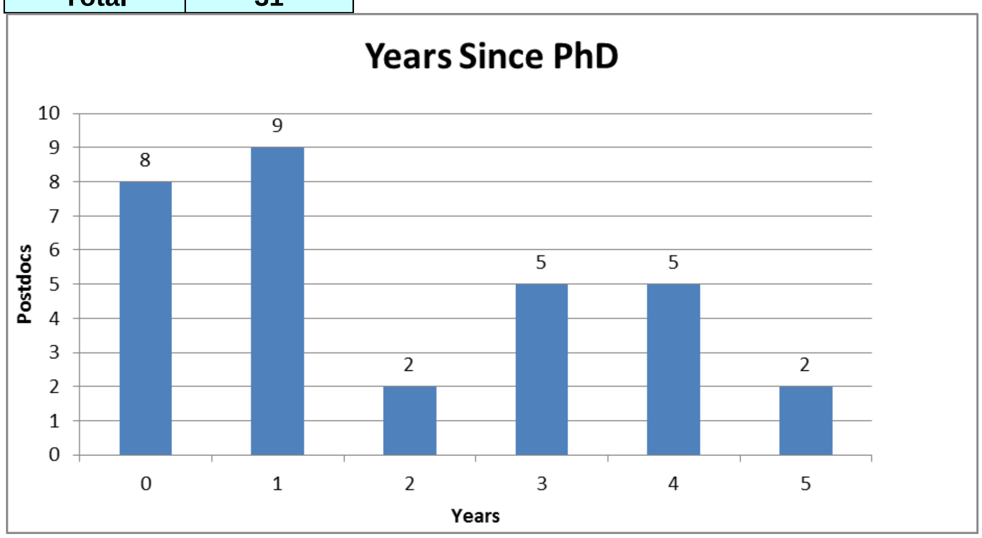
Of the six postdocs who came from Group I Public Institutions, two are currently at Group I Public Institutions, one is at a Group I Private Insitution, and the others are at Group II and Foreign Institutions.

Of the eleven postdocs who came from Foreign Institutions, four returned to Foreign Institutions.

3.3 Postdoctoral Fellow Participant Summary

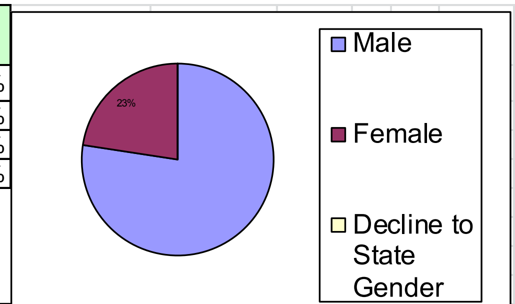
Programs	# of Postdocs	# of Citizens & Perm. Res.	%	# of Female	%	# of Minorities	%	US Home Institution	%
Symplectic and Contact Geometry and Topology	12	3	25.0%	3	25.0%	1	33.3%	5	41.7%
Tropical Geometry	8	3	37.5%	2	25.0%	0	0.0%	3	37.5%
Homology Theory of Knots and Links	8	3	37.5%	3	37.5%	0	0.0%	5	62.5%
Complementary Program 2009-10	2	2	100.0%	0	0.0%	1	50.0%	2	100.0%
External Postdoctoral Fellows Program 2009-10	5	5	100.0%	0	0.0%	1	20.0%	5	100.0%
Total # of *Distinct* Postdocs	**31**	**14**	**45.2%**	**7**	**22.6%**	**2**	**14.3%**	**18**	**58.1%**

Yrs since PhD	# of PD
0	8
1	9
2	2
3	5
4	5
5	2
Total	**31**

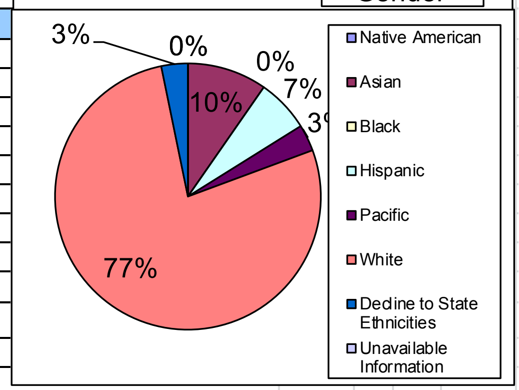


3.4 Postdoctoral Fellow Demographic Data

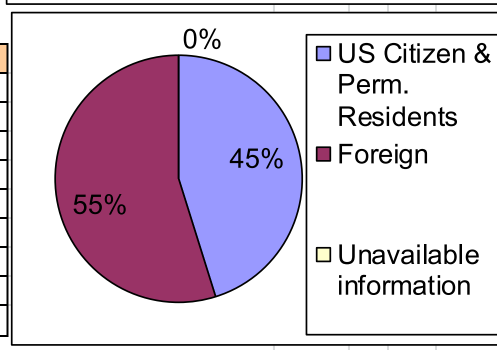
Gender	#	% (No Decl.)*	%
# of Distinct PD	31		100.0%
Male	24	77.42%	77.4%
Female	7	22.58%	22.6%
Decline to State Gender	0		0.0%



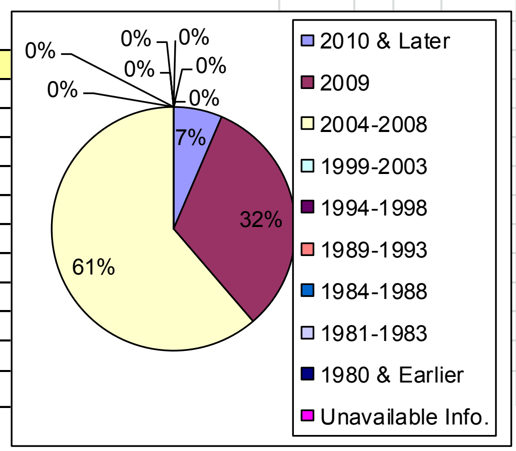
Ethnicities	#	% (No Decl.)*	%
Native American	0	0.00%	0.0%
Asian	3	10.00%	9.7%
Black	0	0.00%	0.0%
Hispanic	2	6.67%	6.5%
Pacific	1	3.33%	3.2%
White	24	80.00%	77.4%
Decline to State Ethnicities	1		3.2%
Unavailable Information	0		0.0%
# of Distinct PD	31		100.0%
Minorities	2		14.3%



Citizenships	#		%
US Citizen & Perm. Residents	14		45.2%
Foreign	17		54.8%
Unavailable information	0		0.0%
# of Distinct PD	31		100.0%
US Citizen	11		35.5%
Perm Residents	3		9.7%
Home Inst. in US	18		58.06%



Year of Ph.D	#		%
2010 & Later	2		6.5%
2009	10		32.3%
2004-2008	19		61.3%
1999-2003	0		0.0%
1994-1998	0		0.0%
1989-1993	0		0.0%
1984-1988	0		0.0%
1981-1983	0		0.0%
1980 & Earlier	0		0.0%
Unavailable Info.	0		0.0%
Total # of Distinct PD	31		100.0%

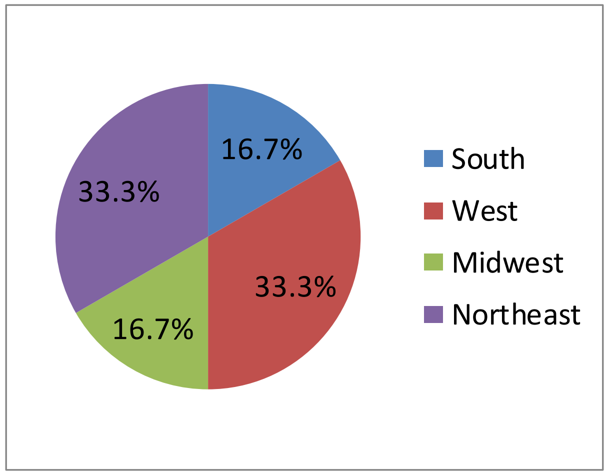


**Statistic Calculation based on all participants that did not decline.*

Home Institution Classified by States

**Regions based on US Census classification*

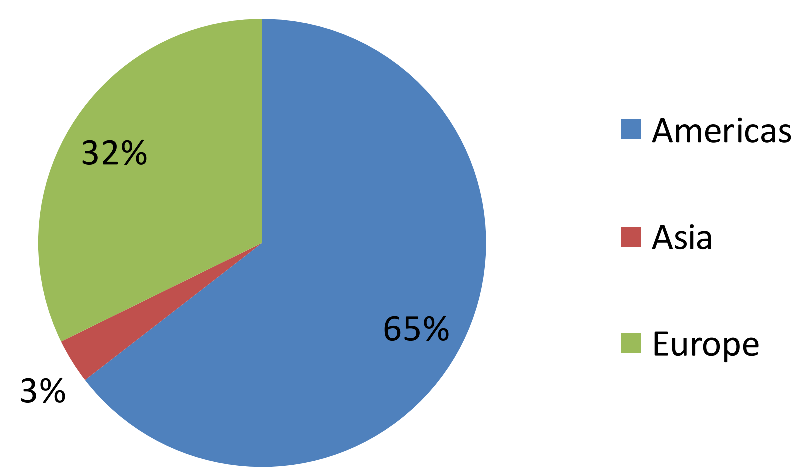
State	#	%	2007 Census
South	**3**	**16.7%**	**36.6%**
AL	-	0.0%	1.5%
AR	-	0.0%	0.9%
DE	-	0.0%	0.3%
DC	1	5.6%	0.2%
FL	-	0.0%	6.1%
GA	-	0.0%	3.2%
KY	-	0.0%	1.4%
LA	-	0.0%	1.4%
MD	-	0.0%	1.9%
MS	-	0.0%	1.0%
NC	1	5.6%	3.0%
OK	-	0.0%	1.2%
SC	-	0.0%	1.5%
TN	-	0.0%	2.0%
TX	1	5.6%	7.9%
VA	-	0.0%	2.6%
WV	-	0.0%	0.6%
West	**6**	**33.3%**	**23.2%**
AK	-	0.0%	0.2%
AZ	1	5.6%	2.1%
HI	-	0.0%	0.4%
ID	-	0.0%	0.5%
MT	-	0.0%	0.3%
CA	4	22.2%	12.1%
CO	-	0.0%	1.6%
NV	-	0.0%	0.9%
NM	-	0.0%	0.7%
OR	-	0.0%	1.2%
UT	1	5.6%	0.9%
WA	-	0.0%	2.1%
WY	-	0.0%	0.2%
Midwest	**3**	**16.7%**	**22.0%**
IL	1	5.6%	4.3%
IN	-	0.0%	2.1%
IA	-	0.0%	1.0%
KS	-	0.0%	0.9%
MI	2	11.1%	3.3%
MN	-	0.0%	1.7%
MO	-	0.0%	1.9%
ND	-	0.0%	0.2%
NE	-	0.0%	0.6%
OH	-	0.0%	3.8%
SD	-	0.0%	0.3%
WI	-	0.0%	1.9%
Northeast	**6**	**33.3%**	**18.1%**
CT	-	0.0%	1.2%
ME	-	0.0%	0.4%
MA	3	16.7%	2.1%
NH	-	0.0%	0.4%
NJ	-	0.0%	2.9%
NY	3	16.7%	6.4%
PA	-	0.0%	4.1%
RI	-	0.0%	0.4%
VT	-	0.0%	0.2%
Total	**18**	**100%**	**100%**



Home Institution Classified by Countries

**Regions based on United Nations classification*

Americas			**20**
	Central America	Mexico	1
	North America	Canada	1
		United States	18
Asia			**1**
	Western Asia	Israel	1
Europe			**10**
	Eastern Europe	Hungary	1
	Northern Europe	England	2
	Western Europe	France	4
		Germany	2
		Switzerland	1
Grand Total			**31**



3.5 Postdoctoral Research Member Placement List

Family Name	First Name	Placement Institution	State	Country	Position	MSRI Mentor	Program
Cautis	Sabin	Columbia University	NY	US	Assistant Professor	Peter Teichner	HTKL
Cotton-Clay	Andrew	Harvard University	MA	US	Postdoc	Denis Auroux	SCGT
Greene	Joshua	Columbia University	NY	US	Postdoc	Rachel Roberts	HTKL
Horn	Peter	Columbia University	NY	US	Postdoc	Peter Ozsvath	HTKL
Manon	Christopher	UC Berkeley	CA	US	Postdoc	David Eisenbud	TG
Maydanskiy	Maksim	Stanford University	CA	US	Postdoc	Yasha Eiashberg	SCGT
Musiker	Gregg	MIT	MA	US	Postdoc	Eva Feichtner	TG
Payne	Sam	Clay Mathematics Institute	MA	US	Postdoc	Ilia Itenberg	TG
Sarkar	Sucharit	Columbia University	NY	US	Postdoc	Peter Ozsvath	HTKL
Tabera	Luis	University of Cantabria		ES	Associate Professor	Grisha Mikhalkin	TG
Vela-Vick	David	Columbia University	NY	US	Postdoc	Peter Ozsvath	HTKL
Yu	Josephine	Georgia Institute of Technology	GA	US	Postdoc	Annette Werner	TG

3.6 Postdoctoral Research Member Summary

Programs	# of PD/RM	# of Citizens & Perm. Res.	%	# of Female	%	# of Minorities	%	US Home Institution	%
Symplectic and Contact Geometry and Topology	2	2	*100.0%*	0	*0.0%*	0	*0.0%*	2	100.0%
Tropical Geometry	5	4	*80.0%*	1	*20.0%*	0	*0.0%*	5	100.0%
Homology Theory of Knots and Links	5	3	*60.0%*	0	*0.0%*	0	*0.0%*	5	100.0%
Complementary Program 2009-10	0	0	*0.0%*	0	*0.0%*	0	*0.0%*	0	0.0%
External Postdoctoral Fellows Program	0	0	*0.0%*	0	*0.0%*	0	*0.0%*	0	0.0%
Total # of PD/RM	**12**	**9**	***75.0%***	**1**	***8.3%***	**-**	***0.0%***	**12**	***100.0%***

4. Graduate Program

In 2009–10, 787 graduate students visited MSRI to participate in our workshops (544 graduate students), summer graduate schools (215 graduate students), and programs (28 graduate students). While the majority of the graduate students who visit MSRI had been invited to take part in one of our workshops or summer graduate schools, a smaller number of graduate students were invited as ‘Program Associates’ in our semester- and year-long scientific programs.

4.1 Summer Graduate Schools (SGS)

Every summer, MSRI organizes several summer graduate schools (usually two weeks each), most of which are held at MSRI. Attending one of these schools can be a very motivating and exciting experience for a student; participants have often said that it was the first experience where they felt like real mathematicians, interacting with other students and mathematicians in their field.

Graduate students from MSRI Academic Sponsoring Institutions or from Department of Mathematics at U.S. Universities are eligible for summer schools. For each institution, MSRI provides support for two students per summer and for a third student if at least one of the students is female or from a group that is underrepresented in the mathematical sciences. MSRI covers travel and local expenses with the maximal allowance for travel reimbursement being \$550 for students from U.S. and Canadian universities (depending on the point of origin), and \$700 for students from other sponsoring institutions.

The application procedure is as follows: The summer graduate schools and the open enrollment period for the summer of year n+1 are announced in October of year n. Graduate students must be nominated by their Director of Graduate Studies during the enrollment period. MSRI accepts nominees on a first-come first-served basis up to the limits of the capacity of each workshop, which is around 40 for workshops that are held at MSRI. If the chosen workshop is already full, the students are either kept on a waiting list or the nominating institution may make nominations to other workshops until its workshop quota is reached.

The following is a list of the six Summer Graduate Schools that took place during the 2009 summer. Altogether 32 lecturers and 215 graduate students participated in these workshops. Of those graduate students, 31% were female. See the table in section 4.4 for detailed demographic data.

For a complete report on each SGS, please refer to the Appendix.

SGS 1: IAS/PCMI Summer Workshop: The Arithmetic of L-Functions (IAS/PCMI)
Location: IAS/Park City Mathematics Institute, Salt Lake City, UT
June 28, 2009 to July 18, 2009
Organized by Cristian Popescu (University of California, San Diego), Karl Rubin (University of California, Irvine), and Alice Silverberg (University of California, Irvine)*

SGS 2: Random Matrix Theory (RMT)
July 06, 2009 to July 17, 2009
Organized by Jinho Baik (University of Michigan), Percy Deift(New York University), Toufic Suidan (University of Arizona), and Brian Rider (University of Colorado at Boulder)*

SGS 3: Computational Theory of Real Redutive Groups (CTRR)
Location: Salt Lake City
*** Held off-site and reported independently to the NSF by workshop organizers***
July 20, 2009 to July 24, 2009
Organized by Jeffrey Adams (University of Maryland), Peter Trapa (University of Utah), Susana Salamanca (New Mexico State University), and John Stembridge (University of Michigan)*

SGS 4: Inverse Problems (IP)
July 20, 2009 to July 31, 2009
Organized by Gunther Uhlmann (University of Washington)*

SGS 5: Symplectic and Contact Geometry and Topology (SCGT)
August 03, 2009 to August 14, 2009
Organized by John Etnyre (Georgia Institute of Technology), Dusa McDuff(Barnard College), and Lisa Traynor (Bryn Mawr College)*

SGS 6: Toric Varieties (TV)
June 15, 2009 to June 26, 2009
Organized by David Cox(Amherst College) and Henry Schenck* (University of Illinois, Urbana)*

4.2 Summer Graduate School Data

Participant List

Participant	Home Institution	Position	Workshop
Cantillo, Jorge	Rutgers University	Graduate Student	IAS/PCMI
Goedhart, Eve	Bryn Mawr College	Graduate Student	IAS/PCMI
Lundell, Benjamin	Cornell University	Graduate Student	IAS/PCMI
Palm, Marc	Virginia Polytechnic Institute and State U.	Graduate Student	IAS/PCMI
Van Garrel, Micheal	California Institute of Technology	Graduate Student	IAS/PCMI
Abduvalieva, Gulnara	Drexel University	Graduate Student	RMT
Al-Sharadqah, Ali	University of Alabama at Birmingham	Graduate Student	RMT
Ampadu, Clement	Central Michigan University	Graduate Student	RMT
Antonioli, John	University of British Columbia	Graduate Student	RMT
Aristoff, David	University of Texas	Graduate Student	RMT
Auffinger, Antonio	New York University	Graduate Student	RMT

Barber, John	Johns Hopkins University	Graduate Student	RMT
Bloemendal, Alex	University of Toronto	Graduate Student	RMT
Corwin, Ivan	New York University	Graduate Student	RMT
Dahl, Janina	Rice University	Graduate Student	RMT
De La Iglesia, Manuel	New York University	Graduate Student	RMT
Hajij, Mustafa	Louisiana State University	Graduate Student	RMT
Holmes, Irina	Louisiana State University	Graduate Student	RMT
Janoski, janine	Clemson University	Graduate Student	RMT
Jenkinson, Justin	Case Western Reserve University	Graduate Student	RMT
Lee, Eunghyun	University of California, Davis	Graduate Student	RMT
Liechty, Karl	Indiana University--Purdue University	Graduate Student	RMT
Liu, Zhipeng	University of Michigan	Graduate Student	RMT
Maltsev, Anna	California Institute of Technology	Graduate Student	RMT
Matayoshi, Jeff	University of California, Irvine	Graduate Student	RMT
Melborne, James	University of Kansas	Graduate Student	RMT
Mitkovski, Misko	Texas A & M University	Graduate Student	RMT
Morales, Pedro	Baylor University	Graduate Student	RMT
Noyes, Mike	University of Colorado	Graduate Student	RMT
O'Rourke, Sean	University of California, Davis	Graduate Student	RMT
Oyoung, Josh	University of California, Davis	Graduate Student	RMT
Prager, David	University of Georgia	Graduate Student	RMT
Rael, Michael	University of California, Irvine	Graduate Student	RMT
Rios Zertuche, Rodolfo	Princeton University	Graduate Student	RMT
Rivasplata, Omar	University of Alberta	Graduate Student	RMT
Spektor, Susanna	University of Alberta	Graduate Student	RMT
Sun, Chung-Kai	University of California, San Diego	Graduate Student	RMT
Vaidyanathan, chandra	University of Missouri	Graduate Student	RMT
Xu, Zhe	Northwestern University	Graduate Student	RMT
Xu, Zhengjie	University of Michigan	Graduate Student	RMT
Yang, Yuting	University of Michigan	Graduate Student	RMT
Zemlyanova, Anna	Texas A & M University	Graduate Student	RMT
Zhi, Weifeng	University of Kentucky	Graduate Student	RMT
Agostiniani, Virginia	Istituto Nazionale di Alta Matematica (INdAM)	Graduate Student	IP
Chang, Eun	Virginia Polytechnic Institute	Graduate Student	IP
Chung, Francis	University of Chicago	Graduate Student	IP
Dai, Mimi	University of California, Santa Cruz	Graduate Student	IP
D'Elia, Marta	Emory University	Graduate Student	IP
Diefenthaler, Kamala	University of South Carolina	Graduate Student	IP
Dyatlov, Semyon	University of California, Berkeley	Graduate Student	IP
Ettinger, Boris	University of California, Berkeley	Graduate Student	IP
Fan, Ying Wai	Emory University	Graduate Student	IP
Georgieva-Hristova, Yulia	Texas A & M University	Graduate Student	IP
Graf, Tobias	Emory University	Graduate Student	IP
Hezari, Hamid	Massachusetts Institute of Technology	Faculty/Postdoc	IP
Hoang, Nguyen	Kansas State University	Graduate Student	IP
Holman, Sean	Purdue University	Faculty/Postdoc	IP
Homa, Laura	Case Western Reserve University	Graduate Student	IP
Hoogeboom, Chris	University of Massachusetts	Graduate Student	IP
Hora, Raphael	Purdue University	Graduate Student	IP
Hubenthal, Mark	University of Washington	Graduate Student	IP

Jafarov, Elchin	University of Alaska	Graduate Student	IP
Jordan-squire, Christopher	Washington University	Graduate Student	IP
Jordon, Daniel	Drexel University	Graduate Student	IP
Kilgore, Kimberly	Drexel University	Graduate Student	IP
LaRussa, Annette	University of Alabama at Birmingham	Graduate Student	IP
Lin, Junshan	Michigan State University	Graduate Student	IP
Lin, Min-Hsiung	North Carolina State University	Graduate Student	IP
Mamonov, Alexander	Rice University	Graduate Student	IP
Marazzi, Leonardo	Purdue University	Graduate Student	IP
McGivney, Debra	Case Western Reserve University	Graduate Student	IP
Oh, Seougly	University of Kansas	Graduate Student	IP
Osorio, Mauricio	University of Cincinnati	Graduate Student	IP
Ozer, Ahmet	Iowa State University	Graduate Student	IP
Rivas, Ivonne	University of Cincinnati	Graduate Student	IP
Seeluangsawat, Paisa	University of South Carolina	Graduate Student	IP
Song, Lei	University of Illinois	Graduate Student	IP
Srinivalamurthy, Suresh	Kansas State University	Graduate Student	IP
Steinhauer, Dustin	University of California, Los Angeles	Graduate Student	IP
Sun, Chung-Kai	University of California, San Diego	Graduate Student	IP
Taylor, Justin	University of Kentucky	Graduate Student	IP
VanValkenburgh, Michael	University of California	Faculty/Postdoc	IP
Weir, Brad	University of Arizona	Graduate Student	IP
Ylinen, Laury	University of Washington	Graduate Student	IP
Zhou, Ting	Unversity of Washington	Graduate Student	IP
Al-Rawashdeh, Waleed	Central Michigan University	Graduate Student	SCGT
Arima, Emi	University of California, Davis	Graduate Student	SCGT
Bao, Erkao	University of Wisconsin	Graduate Student	SCGT
Brandenbursky, Michael	Technion - Israel Institute of Technology	Graduate Student	SCGT
Branson, Mark	Columbia University	Graduate Student	SCGT
Carneiro, Andre	Columbia University	Graduate Student	SCGT
Espina, Jacqueline	University of California	Graduate Student	SCGT
Fitzpatrick, Sean	University of Toronto	Graduate Student	SCGT
Franklin, Bridget	Rice University	Graduate Student	SCGT
Georgieva, Penka	Stanford University	Graduate Student	SCGT
Gospodinov, Georgi	Olin College of Engineering	Faculty/Postdoc	SCGT
Gripp, Vinicius	University of California, Berkeley	Graduate Student	SCGT
Hein, Doris	University of California, Berkeley	Graduate Student	SCGT
Hom, Jennifer	University of Pennsylvania	Graduate Student	SCGT
Hong, hansol	Seoul National University	Graduate Student	SCGT
Huang, Yang	University of Southern California	Graduate Student	SCGT
Jones, Korri	Howard University	Graduate Student	SCGT
Kaloti, Amey	Georgia Institute of Technology	Graduate Student	SCGT
Kang, Sooran	University of Colorado	Graduate Student	SCGT
Khonggkha, Poranee	University of Cincinnati	Graduate Student	SCGT
Kinlaw, Paul	Dartmouth College	Graduate Student	SCGT
LaFountain, Doug	University at Buffalo (SUNY)	Graduate Student	SCGT
Lanzat, Sergei	Technion---Israel Institute of Technology	Graduate Student	SCGT
Lee, Brandyn	University of North Carolina	Graduate Student	SCGT
Lu, Ni	University of Hawaii at Manoa	Graduate Student	SCGT
Mansaku, Shkelzen	Kansas State University	Graduate Student	SCGT

Mansfield, Laura	Bryn Mawr College	Graduate Student	SCGT
Ma'u, Sikimeti	Barnard College	Faculty/Postdoc	SCGT
Mesa, Camilo	University of Colorado	Graduate Student	SCGT
Micklewright, Christopher	Bryn Mawr College	Graduate Student	SCGT
Montgomery, Whitney	University of Georgia	Graduate Student	SCGT
Mossa, Roberto	Istituto Nazionale di Alta Matematica (INdAM)	Graduate Student	SCGT
Nelson, Joanna	University of Wisconsin	Graduate Student	SCGT
Park, Heesang	Seoul National University	Graduate Student	SCGT
Rice, Danielle	Portland State University	Graduate Student	SCGT
Rose, David	Duke University	Graduate Student	SCGT
Rueckriemen, Ralf	Dartmouth College	Graduate Student	SCGT
Sahattchieve, Jordan	University of Michigan	Graduate Student	SCGT
Schneider, Greg	State University College, SUNY	Graduate Student	SCGT
Sealy, Matt	University of Missouri	Graduate Student	SCGT
Shaw, Kristin	University of Toronto	Graduate Student	SCGT
Smith, Aaron	University of Pennsylvania	Graduate Student	SCGT
Tanaka, Hiroaki	Northwestern University	Graduate Student	SCGT
Venugopalan, Sushmita	Rutgers University	Graduate Student	SCGT
Wang, Dongning	University of Wisconsin	Graduate Student	SCGT
Yazinski, Jonathan	Indiana University	Graduate Student	SCGT
Gudmundsson, Hilmar	Reykjavik University	Graduate Student	TV
Hardarson, Marteinn	Reykjavik University	Graduate Student	TV
Hinkelmann, Franziska	Virginia Polytechnic Institute	Graduate Student	TV
Hsiao, Jen-Chieh	Purdue University	Graduate Student	TV
Kazanova, Anna	University of Massachusetts	Graduate Student	TV
Kodgis, Lisa	University of Hawaii	Graduate Student	TV
Kositwattanarerk, wittawat	Clemson University	Graduate Student	TV
Lin, Kuei-Nuan	Purdue University	Graduate Student	TV
Lin, Jan-Li	Indiana University, Bloomington	Graduate Student	TV
Malmskog, Elizabeth	Colorado State University	Graduate Student	TV
Mahmood, Fatima	Cornell University	Graduate Student	TV
Mathews, Bryant	University of California, Los Angeles	Graduate Student	TV
Miller, Jason	Ohio State University	Graduate Student	TV
Mondal, Pinaki	University of Toronto	Graduate Student	TV
Mukhopadhyay, Swarnava	University of North Carolina	Graduate Student	TV
Kang, Ning	University of Texas, Austin	Graduate Student	TV
Novoseltsev, Andrey	University of Alberta	Graduate Student	TV
O'Keefe, Augustine	Tulane University	Graduate Student	TV
Pabiniak, Milena	Cornell University	Graduate Student	TV
Pham, Vinh An	University of Missouri	Graduate Student	TV
Ravikumar, Vijay	Rutgers University	Graduate Student	TV
Sachitano, David	California State University	Graduate Student	TV
Seceleanu, Alexandra	University of Illinois at Urbana-Champaign	Graduate Student	TV
Shao, Yijun	University of Arizona	Graduate Student	TV
Slawinski, Mike	University of California, San Diego	Graduate Student	TV
Sweet, Ross	Boston University	Graduate Student	TV
Tian, Zhiyu	SUNY	Graduate Student	TV
Trentacoste, Catherin	Clemson University	Graduate Student	TV
Wechter, Matthew	University of Illinois Chicago	Graduate Student	TV
Whitney, Josh	University of California, Irvine	Graduate Student	TV

Xie, Yu	Purdue University	Graduate Student	TV
Li, Zhiyuan	Rice University	Graduate Student	TV
Zhong, Changlong	University of Southern California	Graduate Student	TV
Zhu, Yi	SUNY Stony Brook	Graduate Student	TV
Beaudry, Agnes	Northwestern University	Graduate Student	TV
Brannetti, Silvia	Terza Università di Roma	Graduate Student	TV
Cartwright, Dustin	University of California, Berkeley	Graduate Student	TV
Chowdhury, Atoshi	Stanford University	Graduate Student	TV
Chung, KiRyong	Seoul National University	Graduate Student	TV
Contois, Mark	University of Washington	Graduate Student	TV
Diemer, Colin	University of Pennsylvania	Graduate Student	TV
Dover, James	University of Oklahoma	Graduate Student	TV
Duncan, Alex	University of British Columbia	Graduate Student	TV
Dutle, Aaron	University of South Carolina	Graduate Student	TV
Erman, Daniel	University of California, Berkeley	Graduate Student	TV
Escobar, Laura	San Francisco State University	Graduate Student	TV
Gibbins, Aliska	Ohio State University	Graduate Student	TV
Williams, Harold	University of California, Berkeley	Graduate Student	TV
Chan, Melody	University of California, Berkeley	Graduate Student	TV

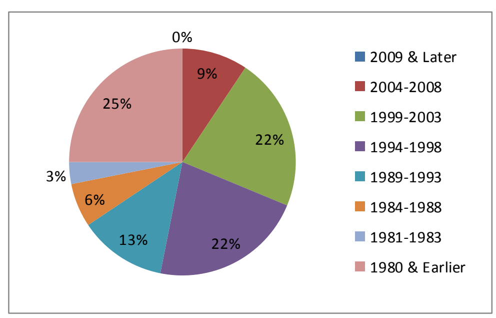
Summer Graduate Schools Summary

Name of Activity	# of Participants	# of Citizens & Permanent Residents	%	# of Female	%	#. of Minorities	%	US Home Institution	%
6 Summer Graduate Schools									
IAS/PCMI Summer Program: The Arithmetic of L-functions	5	1	20%	1	20%	0	0%	5	100%
Random Matrix Theory	38	16	42%	8	21%	1	6%	34	89%
Computational Theory of Real Reductive Groups ***	35	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Inverse Problems	42	16	38%	12	29%	1	6%	41	98%
Symplectic and Contact Geometry and Topology	46	20	43%	17	37%	1	5%	39	85%
Toric Varieties	49	24	49%	18	37%	0	0%	42	86%
6 Summer Graduate Schools Total	**215**	**77**	**36%**	**56**	**31%**	**3**	**4%**	**161**	**89%**

*** Because the workshop located off-site, MSRI was not able to collect participants' demographic data.

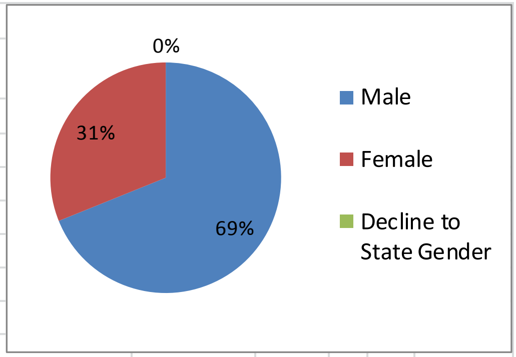
Organizers & lecturers' year of PhD

2009 & Later	0
2004-2008	3
1999-2003	7
1994-1998	7
1989-1993	4
1984-1988	2
1981-1983	1
1980 & Earlier	8
Total	**32**

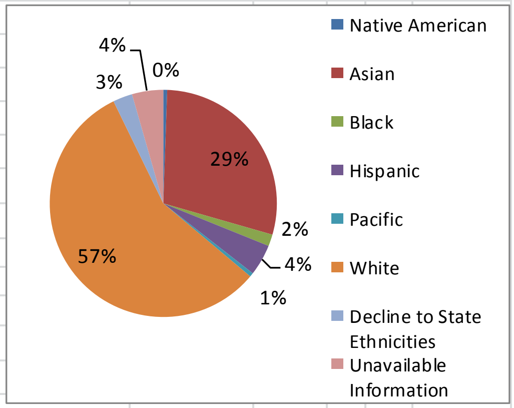


Summer Graduate Schools Demographic Data

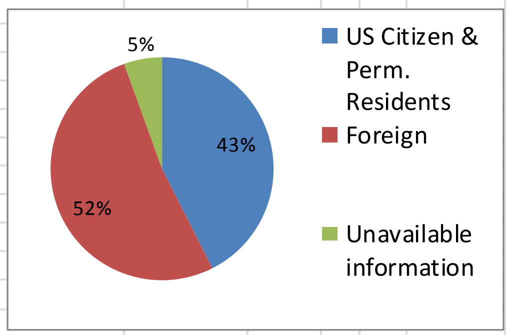
Gender	#	% (No Decl.)*	%
# of Participants	180		100.0%
Male	124	68.89%	68.9%
Female	56	31.11%	31.1%
Decline to State Gender	0		0.0%



Ethnicities	#	% (No Decl.)*	%
Native American	1	0.60%	0.6%
Asian	52	31.14%	28.9%
Black	3	1.80%	1.7%
Hispanic	8	4.79%	4.4%
Pacific	1	0.60%	0.6%
White	102	61.08%	56.7%
Decline to State Ethnicities	5		2.8%
Unavailable Information	8		4.4%
Total # of participants	180		100.0%
Minorities	3		3.9%



Citizenships	#		%
US Citizen & Perm. Residents	77		42.8%
Foreign	94		52.2%
Unavailable information	10		5.6%
# of participants	180		100.6%
US Citizen	74		41.1%
Perm Residents	3		1.7%
Home Inst. in US	161		89.44%



**Statistic Calculation based on all participants that did not decline.*

6 Summer Graduate Schools in 2009:

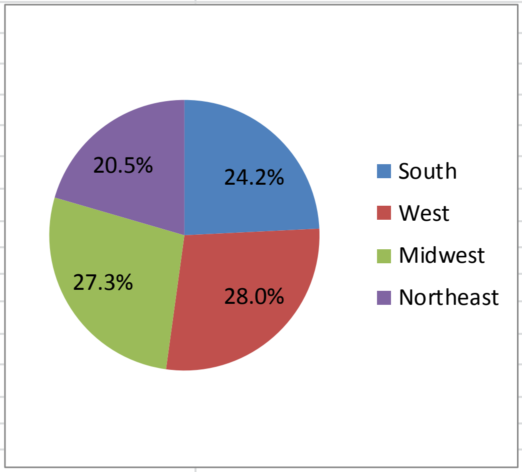
IAS/PCMI Summer Program: The Arithmetic of L-functions
Random Matrix Theory
Inverse Problems
Symplectic and Contact Geometry and Topology
Toric Varieties

Computational Theory of Real Reductive Groups (was not included in Demographic Summary)

Home Institution Classified by States

**Regions based on US Census classification*

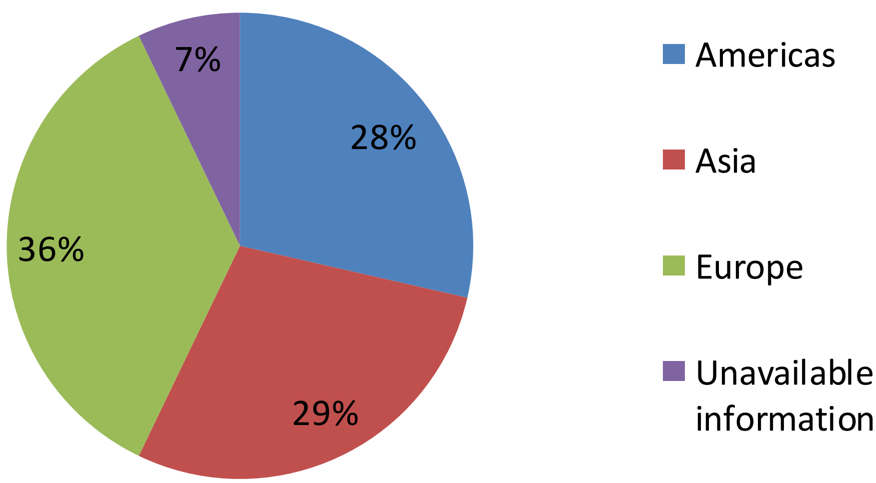
State	#	%	2007 Census
South	**39**	**24.2%**	**36.6%**
AL	2	1.2%	1.5%
AR	-	0.0%	0.9%
DE	-	0.0%	0.3%
DC	1	0.6%	0.2%
FL	-	0.0%	6.1%
GA	6	3.7%	3.2%
KY	2	1.2%	1.4%
LA	3	1.9%	1.4%
MD	1	0.6%	1.9%
MS	-	0.0%	1.0%
NC	4	2.5%	3.0%
OK	1	0.6%	1.2%
SC	6	3.7%	1.5%
TN	-	0.0%	2.0%
TX	10	6.2%	7.9%
VA	3	1.9%	2.6%
WV	-	0.0%	0.6%
West	**45**	**28.0%**	**23.2%**
AK	1	0.6%	0.2%
AZ	2	1.2%	2.1%
HI	2	1.2%	0.4%
ID	-	0.0%	0.5%
MT	-	0.0%	0.3%
CA	32	19.9%	12.1%
CO	4	2.5%	1.6%
NV	-	0.0%	0.9%
NM	-	0.0%	0.7%
OR	1	0.6%	1.2%
UT	-	0.0%	0.9%
WA	3	1.9%	2.1%
WY	-	0.0%	0.2%
Midwest	**44**	**27.3%**	**22.0%**
IL	7	4.3%	4.3%
IN	9	5.6%	2.1%
IA	1	0.6%	1.0%
KS	4	2.5%	0.9%
MI	7	4.3%	3.3%
MN	-	0.0%	1.7%
MO	5	3.1%	1.9%
ND	-	0.0%	0.2%
NE	-	0.0%	0.6%
OH	8	5.0%	3.8%
SD	-	0.0%	0.3%
WI	3	1.9%	1.9%
Northeast	**33**	**20.5%**	**18.1%**
CT	-	0.0%	1.2%
ME	-	0.0%	0.4%
MA	6	3.7%	2.1%
NH	2	1.2%	0.4%
NJ	4	2.5%	2.9%
NY	13	8.1%	6.4%
PA	8	5.0%	4.1%
RI	-	0.0%	0.4%
VT	-	0.0%	0.2%
Other	-	**0.0%**	**0%**
PR	-	0.0%	0%
Other	-	0.0%	0%
Total	**161**	**100%**	**100%**



Home Institution Classified by Countries

**Regions based on United Nations classification*

Americas			**170**
	North America		**170**
		Canada	9
		United States	161
Asia			**4**
	Eastern Asia		**3**
		Korea, Republic of	3
	Western Asia		**1**
		Israel	1
Europe			**5**
	Southern Europe		**3**
		Italy	3
	Northern Europe		**2**
		Iceland	2
Unavailable information			1
Grand Total			**180**



4.3 Program Associates

Program Associates benefit greatly from the opportunity to interact with leaders of a field and postdoctoral fellows, gaining intense exposure to current ideas and trends in their area of specialization. While MSRI does not have the financial resources to fund the Program Associates, they are closely supervised and essentially benefit from all members' privileges. They are provided with an access card to the building which allows them to use the premises at any time. They receive a bus pass, and a library and sports facilities access pass. There were 28 graduate students who resided at MSRI for an extended period of time during the academic year 2009-10. Of those students, 29% were female. See the table in section 4.7 for a detailed description of the demographic data.

The year-long program in Symplectic and Contact Geometry and Topology and the Fall semester program in Tropical Geometry hosted the majority of the program associates.

In the Symplectic and Contact Geometry and Topology Program, a large group of UC Berkeley graduate students participated in the program alongside the program associates. Many graduate students made significant progress in their research. For example:

- Jennifer Hom completed a paper titled "A note on cabling and L-space surgeries" and worked on a preliminary draft of another paper.
- Yuan Huang completed his work on a convex surface theory proof of Elisahberg's well-known theorem on this subject.

In the Tropical Geometry Program, weekly graduate student seminars were organized by Alex Fink and Franziska Schroter. In addition, a more informal 'What-Is' seminar was organized as a forum for program associates and postdocs to interact and to learn about relevant mathematical concepts. Here are a few research projects undertaken by program associates in Tropical Geometry:

- Angelica Cueto published an article on the geometry of the restricted Boltzmann machine. This is her joint work with Jason Morton and Bernd Sturmfels.
- Alex Fink was invited to speak at the research workshop in October where he presented his project on tropical cycles and Chow polytopes.
- Benjamin Iriarte wrote a paper on Phylogenetic trees and the tropical Grassmannian. (One of the main problems in evolutionary biology is that of reconstructing a phylogenetic tree from a DNA sequence alignment of n species. This process is considerably simplified by the distance-based approach.)

4.4 Program Associates Data

Participant List

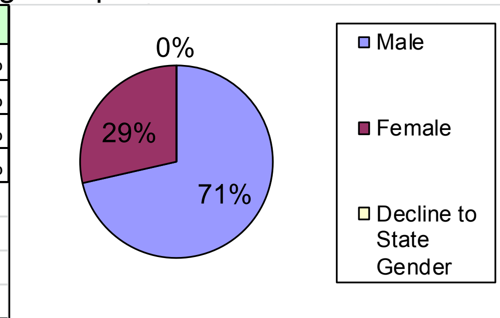
Program Associate	Home Institution	Position	Program
Bloom, Jonathan	Columbia University	Graduate Student	HTKL
Diogo, Luis	Stanford University	Graduate Student	SCGT
Frenk, Bart	Technische Universiteit Eindhoven	Graduate Student	TG
Fromm, Viktor	University of Durham	Graduate Student	SCGT
Garay, Cristhian	Université de Paris VII (Denis Diderot)	Graduate Student	TG
Georgieva, Penka	Stanford University	Graduate Student	SCGT
Gerstenberger, Andreas	Ludwig-Maximilians-Universität München	Graduate Student	SCGT
Gilmore, Allison	Columbia University	Graduate Student	HTKL
Grigoriev, Ilya	Stanford University	Graduate Student	SCGT
Haebich, Mathias	Johann Wolfgang Goethe-Universität Frankfurt	Graduate Student	TG
Hendricks, Kristen	Columbia University	Graduate Student	HTKL
Herold, Matthias	TU Kaiserslautern	Graduate Student	TG
Hom, Jennifer	University of Pennsylvania	Graduate Student	SCGT
Huang, Yang	University of Southern California	Graduate Student	SCGT
Johansson, Petter	Stockholm University	Graduate Student	TG
Levine, Adam	Columbia University	Graduate Student	HTKL
Lewallen, Sam	Princeton University	Graduate Student	HTKL
Meyer, Henning	Universität Kaiserslautern	Graduate Student	TG
Murphy, Max	Stanford University	Graduate Student	SCGT
Petkova, Ina	Columbia University	Graduate Student	HTKL
Rau, Johannes	Technische Universitaet Kaiserslautern	Graduate Student	TG
Schroeter, Franziska	Georg-August-Universität zu Göttingen	Graduate Student	TG
Shaw, Kristin	University of Toronto	Graduate Student	TG
Sheikhalishahi, Akram	Sharif University of Technology	Graduate Student	HTKL
Slawinski, Mike	University of California	Graduate Student	TG
Tosun, Bulent	Georgia Insitute of Technology	Graduate Student	SCGT
Tsai, Chung-Jun	Harvard University	Graduate Student	SCGT
Zarev, Rumen	Columbia University	Graduate Student	HTKL

Program Associates Summary

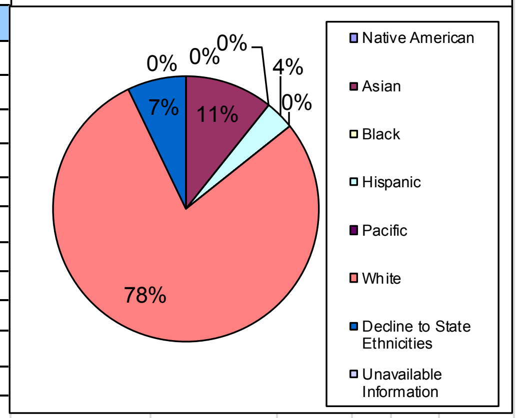
Programs	# of Program Associates	# of Citizens & Perm. Res.	%	# of Female	%	# of Minorities	%	US Home Institution	%
Symplectic and Contact Geometry and Topology	10	3	*30.0%*	2	*20.0%*	0	*0.0%*	8	80.0%
Tropical Geometry	10	1	*10.0%*	2	*20.0%*	0	*0.0%*	1	10.0%
Homology Theory of Knots and Links	8	5	*62.5%*	4	*50.0%*	0	*0.0%*	7	87.5%
Complementary Program 2009-10	0	0	*0.0%*	0	*0.0%*	0	*0.0%*	0	0.0%
External Postdoctoral Fellows Program	0	0	*0.0%*	0	*0.0%*	0	*0.0%*	0	0.0%
Total no. of Program Associates	**28**	**9**	***32.1%***	**8**	***28.6%***	**-**	***0.0%***	**16**	***57.1%***

Program Associates Demographic Data

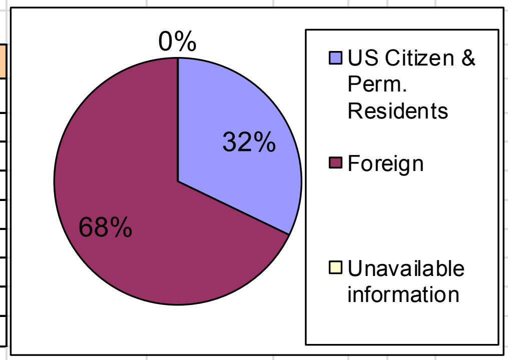
Gender	#	% (No Decl.)*	%
# of Program Associates	28		100.0%
Male	20	71.43%	71.4%
Female	8	28.57%	28.6%
Decline to State Gender	0		0.0%



Ethnicities	#	% (No Decl.)*	%
Native American	0	0.00%	0.0%
Asian	3	11.54%	10.7%
Black	0	0.00%	0.0%
Hispanic	1	3.85%	3.6%
Pacific	0	0.00%	0.0%
White	22	84.62%	78.6%
Decline to State Ethnicities	2		7.1%
Unavailable Information	0		0.0%
# of Program Associates	28		100.0%
Minorities	0		0.0%



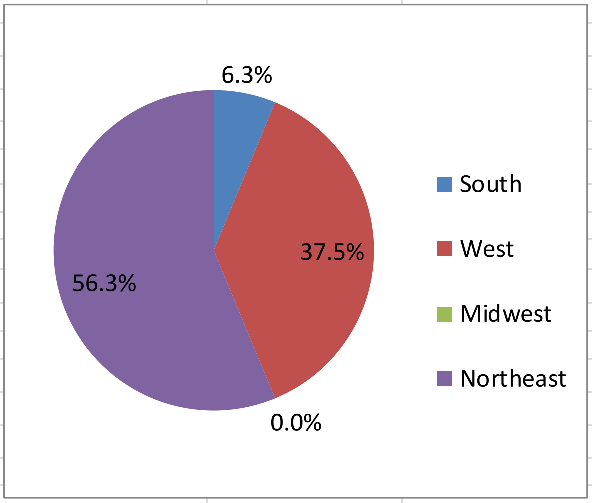
Citizenships	#		%
US Citizen & Perm. Residents	9		32.1%
Foreign	19		67.9%
Unavailable information	0		0.0%
# of Program Associates	28		100.0%
US Citizen	9		32.1%
Perm Residents	0		0.0%
Home Inst. in US	16		57.14%



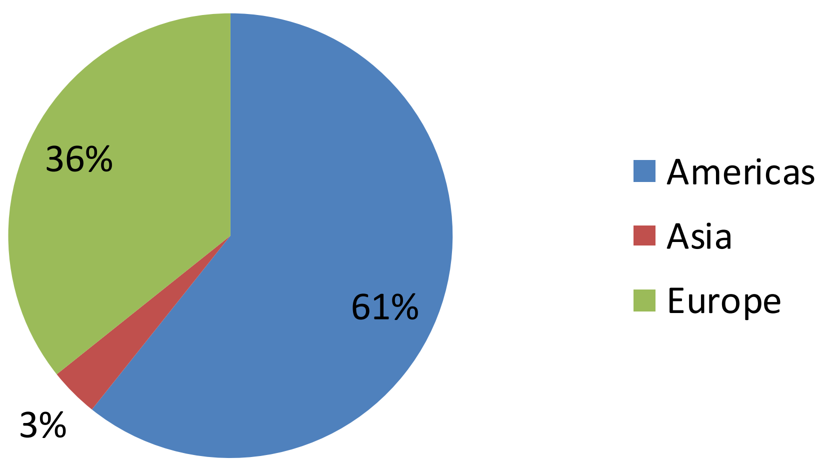
Home Institution Classified by States

**Regions based on US Census classification*

State	#	%	2007 Census
South	**1**	**6.3%**	**36.6%**
AL	-	0.0%	1.5%
AR	-	0.0%	0.9%
DE	-	0.0%	0.3%
DC	-	0.0%	0.2%
FL	-	0.0%	6.1%
GA	1	6.3%	3.2%
KY	-	0.0%	1.4%
LA	-	0.0%	1.4%
MD	-	0.0%	1.9%
MS	-	0.0%	1.0%
NC	-	0.0%	3.0%
OK	-	0.0%	1.2%
SC	-	0.0%	1.5%
TN	-	0.0%	2.0%
TX	-	0.0%	7.9%
VA	-	0.0%	2.6%
WV	-	0.0%	0.6%
West	**6**	**37.5%**	**23.2%**
AK	-	0.0%	0.2%
AZ	-	0.0%	2.1%
HI	-	0.0%	0.4%
ID	-	0.0%	0.5%
MT	-	0.0%	0.3%
CA	6	37.5%	12.1%
CO	-	0.0%	1.6%
NV	-	0.0%	0.9%
NM	-	0.0%	0.7%
OR	-	0.0%	1.2%
UT	-	0.0%	0.9%
WA	-	0.0%	2.1%
WY	-	0.0%	0.2%
Midwest	**-**	**0.0%**	**22.0%**
IL	-	0.0%	4.3%
IN	-	0.0%	2.1%
IA	-	0.0%	1.0%
KS	-	0.0%	0.9%
MI	-	0.0%	3.3%
MN	-	0.0%	1.7%
MO	-	0.0%	1.9%
ND	-	0.0%	0.2%
NE	-	0.0%	0.6%
OH	-	0.0%	3.8%
SD	-	0.0%	0.3%
WI	-	0.0%	1.9%
Northeast	**9**	**56.3%**	**18.1%**
CT	-	0.0%	1.2%
ME	-	0.0%	0.4%
MA	1	6.3%	2.1%
NH	-	0.0%	0.4%
NJ	1	6.3%	2.9%
NY	6	37.5%	6.4%
PA	1	6.3%	4.1%
RI	-	0.0%	0.4%
VT	-	0.0%	0.2%
Total	**16**	**100%**	**100%**



Home Institution Classified by Countries			
*Regions based on United Nations classification			
Americas			**17**
	North America		**17**
		Canada	1
		United States	16
Asia			**1**
	South-Central Asia		**1**
		Iran	1
Europe			**10**
	Northern Europe		**2**
		England	1
		Sweden	1
	Western Europe		**8**
		France	1
		Germany	6
		Netherlands	1
Grand Total			**28**



4.5 Graduate Student (attended 2009-10 workshops) List

(See e-mail attached file)

4.6 Graduate Student (attended 2009-10 workshops, excluding SGS) Data

Name of Activity	# of Graduate Students	# of Citizens & Permanent Residents	%	# of Female	%	#. of Minorities	%	US Home Institution	%
16 Scientific Workshops									
Connections for Women: Tropical Geometry	37	14	38%	22	59%	2	14%	22	59%
Introductory Workshop: Tropical Geometry	46	12	26%	15	33%	1	8%	22	48%
Tropical Geometry in Combinatorics and Algebra	28	7	25%	12	43%	1	14%	10	36%
Tropical Structures in Geometry and Physics	26	10	38%	6	23%	1	10%	14	54%
Algebraic Structures in the Theory of Holomorphic Curves	32	11	34%	5	16%	0	0%	22	69%
Symplectic and Contact Topology and Dynamics: Puzzles and Horizons	40	9	23%	15	38%	0	0%	28	70%
Connections for Women: Symplectic and Contact Geometry and Topology	14	5	36%	13	93%	0	0%	8	57%
Introductory Workshop: Symplectic and Contact Geometry and Topology	55	15	27%	11	20%	0	0%	34	62%
Symplectic and Poisson Geometry in interaction with Algebra, Analysis and Topology	22	9	41%	2	9%	1	11%	19	86%
Symplectic Geometry, Noncommutative Geometry and Physics	21	8	38%	2	10%	1	13%	17	81%
Connections for Women: Homology Theories of Knots and Links	31	21	68%	23	74%	2	10%	26	84%
Introductory Workshop: Homology Theories of Knots and Links	69	46	67%	23	33%	4	9%	63	91%
Research Workshop: Homology Theories of Knots and Links	53	30	57%	16	30%	2	7%	45	85%
Hot Topics: Black Holes in Relativity	15	5	33%	3	20%	1	20%	11	73%
Bay Area Differential Geometry Seminar (November 2009)	6	3	50%	0	0%	0	0%	3	50%
Bay Area Differential Geometry Seminar (April 2010)	11	2	18%	1	9%	0	0%	2	18%
16 Scientific Workshops Total	**506**	**207**	**41%**	**169**	**33%**	**16**	**8%**	**346**	**68%**
3 Outreach & Diversity Workshops									
Summer Institute for the Professional Development of Middle School Teachers on Pre-Algebra (Wu Summer Institute July 2009)	20	20	100%	14	70%	0	0%	20	100%
Critical Issues in Mathematics Education: Reasoning and Sense-Making in the Math Curriculum	10	9	90%	5	50%	2	22%	10	100%
Circle on the Road (March 2010)	8	6	75%	3	38%	0	0%	7	88%
3 Outreach & Diversity Workshops Total	**38**	**35**	**92%**	**22**	**58%**	**2**	**6%**	**37**	**97%**
All 19 Workshops Total	**544**	**242**	**44%**	**191**	**35%**	**18**	**7%**	**383**	**70%**

5. Undergraduate Program (MSRI-UP)

5.1 Description of Undergraduate Program

Research Topic: Elliptic Curves and Applications
Date: June 12, 2010 to July 25, 2010
Organizers: Ivelisse Rubio, Duane Cooper*, Ricardo Cortez, Herbert Medina, Suzanne Weekes

The MSRI-UP summer program is designed for undergraduate students who have completed two years of university-level mathematics courses and would like to conduct research in the mathematical sciences. Due to funding restrictions, only U.S. citizens and permanent residents are eligible to apply, and the program cannot accept foreign students regardless of funding. The academic portion of the 2010 program will be led by Dr. Edray Goins.

During the summer, each of the 18 student participants

- participated in the mathematics research program under the direction of Dr. Goins,
- completed a research project done in collaboration with other MSRI-UP students,
- gave a presentation and wrote a technical report on his/her research project,
- attended a series of colloquium talks given by leading researches in their fields,
- attended workshops aimed at developing skills and techniques needed for research careers in the mathematical sciences,

- acquired techniques that will maximize a student's likelihood of admissions to graduate programs as well as the likelihood of winning fellowships, and
- received a $3000 stipend, lodging, meals, and roundtrip travel to Berkeley, CA.

After the summer, each student

- had an opportunity to attend a national mathematics or science conference where students presented their research,
- became part of a network of mentors that provides continuous advice in the long term as the student makes progress in his/her studies, and
- was contacted regarding future research opportunities.

The main objective of MSRI-UP 2010 was to identify talented students, especially those from underrepresented groups, who are interested in mathematics and to make available to them meaningful research opportunities, the necessary skills and knowledge to participate in successful collaborations, and a community of academic peers and mentors who can advise, encourage, and support them through a successful graduate program.

The objective was designed to contribute significantly toward meeting the program goal of increasing the number of graduate degrees in the mathematical sciences, especially doctorates, earned by U.S. citizens and permanent residents by cultivating heretofore untapped mathematical talent within the U.S. Black, Hispanic/Latino, and Native American communities.

MSRI is delighted to announce that two of the students who participated in the MSRI-UP 2007 were awarded 2010 NSF Graduate Research Fellowships. They are Talea Mayo and Gina Pomann.

Topic: Elliptic Curves and Applications

An elliptic curve E is an arithmetic-algebraic object: It is simultaneously a nonsingular projective curve with an affine equation, which allows one to perform arithmetic on its points, and a finitely generated abelian group, which allows one to apply results from abstract algebra. The goal for this summer was to learn about elliptic curves and give applications by using their properties to study problems in other fields.

Students completed a short course for two (2) weeks to cover any necessary background from abstract algebra and discrete mathematics. For the remainder of the program, the students broke up into smaller groups and worked on research projects. They had a choice of one of the following projects:

Project 1: ABC Conjecture

This deceptively simple question was first outlined in 1985 by Joseph Oesterlé and David Masser. Consider three relatively prime positive integers A, B, C, such that A+B=C. Let rad(ABC) denote the product of the distinct prime factors of ABC. Computational evidence suggests that it is rare to have C > rad(ABC). To be more precise, given any positive number e, there should only exist finitely many (A:B:C) such that the quantity q(A:B:C) = log(C)/log(rad(ABC)) is greater than 1+e.

This project seeks to use elliptic curves to search for triples (A:B:C) with exceptionally large q(A:B:C). The approach will be to use properties of certain families of elliptic curves that are classified according to their isogenous curves. For example, the triple (3^3:5:2^5) has a rather low quality of q=1.01898, whereas the triple (3:5^3:2^7) has a rather large quantity q=1.42657. These triples correspond to elliptic curves which are 3-isogeneous to each other.

Project 2: Elliptic Curve Cryptography

There are two aspects when discussing secrets: how to safely encrypt a message so that an unauthorized party cannot read it and how to effectively decrypt a message so that an authorized party can. This project sought to have students learn about the Discrete Logarithm Problem by writing computer code. Students engaged in a friendly competition of passing secrets: one encrypted, while the other eavesdroped!

The method of encryption using elliptic curves is a type of Public Key cryptosystem, an idea first put forth by Whitfield Diffie and Martin Hellman in 1976. One takes a message, expresses each character as a positive integer (using say UTF-8), then encodes the message as a positive integer. One can then perform mathematics on this integer, using a shared elliptic curve, and then send this encrypted message to a friend. This process is known as Elliptic Curve Diffie-Hellman (ECDH).

The method of decrypting using elliptic curves is a variant of Pollard's (p-1) Algorithm, an idea first put forth by Hendrik Lenstra in 1987. One wishes to solve the Elliptic Curve Discrete Logarithm Problem (ECDLP) by factoring an integer using elliptic curves. One chooses a random point on a random elliptic curve and then uses the group law to eventually find a factor that allows one to invert the discrete logarithms. This process is known as Elliptic Curve Factorization Method (ECM).

Short Biographies of the 2010 MSRI-UP organizers:

Ivelisse M. Rubio was born and raised in Puerto Rico. She received her B.S. and M.S. in Mathematics from the University of Puerto Rico-Río Piedras and her Ph.D. in Applied Mathematics from Cornell University. In 1998, she co-founded the NSF-REU Summer Institute in Mathematics for Undergraduates (SIMU) at the UPR-Humacao. Ive is currently a Professor in the Computer Science Department at the UPR-Rio Piedras. Her research interests are finite fields and applications to error-correcting codes.

Edray Herbert Goins grew up in South Los Angeles, California. A product of the LAUSD public school system, Dr. Goins attended the California Institute of Technology, where he majored in mathematics and physics. He earned his doctorate in mathematics from Stanford University. Dr. Goins is currently an Assistant Professor of Mathematics at Purdue University in West Lafayette, Indiana. He works in the field of number theory as it pertains to the intersection of representation theory and algebraic geometry.

Dr. Goins spends most of his summers engaging underrepresented students in research in the mathematical sciences. He has taught mathematics with the Vanguard Engineering Scholarship Program through the National Action Council for Minorities in Engineering (NACME), taught mathematics and physics in the Freshman Summer Institute (FSI) at Caltech, and he led a research seminar in number theory in the Summer Undergraduate Mathematical Sciences Research Institute (SUMSRI) at Miami University.

Herbert A. Medina is a Professor of Mathematics at Loyola Marymount University. He completed his undergraduate studies at UCLA and Ph.D. at UC Berkeley. He is an analyst and has done work in Hilbert space operators (of a certain type) and some theoretical aspects of wavelets. He has also dabbled in other elementary math topics. Professor Medina has been involved in many undergraduate summer programs, including five summers as co-director of an REU at the University of Puerto Rico-Humacao.

5.2 MSRI-UP Data

Participants List

Participants	Home Institution
Ayala, Jose Amilcar	California State Polytechnic University
Barrios, Alexander Jesus	Brown University
Brady, Renee	Florida A&M University
Cervantes, Juan	Lewis & Clark University
Davis, Naleceia N	Spelman College
Diaz, Alexander	Universidad de Puerto Rico
Flores, Zachary Joseph	Michigan State University
Jones, Erin	Carleton College
Kinderknecht, Kelsy Danae	University of Kansas
Ly, Megan Danielle	Loyola Marymount University
Nesbitt, Keatra Lynn	University of Northern Colorado
Skeete, Toya N	Spelman College
Tillman, Caleb T	Reed College
Tracy, Anna Marie	Sewanee University
Tsosie, Shawn	University of Massachusetts
Urresta, Lyda Pamela	Union College
Vasquez, Markus Antonio	Oklahoma State University
Watts, Charles D	Morehouse College

6. Appendix – Final Reports

REPORT ON THE SEMESTER PROGRAM "TROPICAL GEOMETRY"

EVA-MARIA FEICHTNER, ILIA ITENBERG,
GRIGORY MIKHALKIN AND BERND STURMFELS

MSRI BERKELEY, FALL 2009

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2. Participants 2
3. Organizatorial Structure 2
4. Synergistic Activities 2
5. Workshops 2
6. Research Developments 5
7. Postdocs 7
8. Graduate Students 14
9. Nuggets and Breakthroughs 16

1. Introduction

Recent years have seen a tremendous development in *Tropical Geometry* that both established the field as an area of its own right and unveiled its deep connections to numerous branches of pure and applied mathematics. Formally speaking, Tropical Geometry is the algebraic geometry over the tropical semiring $\mathbb{R} \cup \{\infty\}$ with operations $x \oplus y := \min\{x, y\}$ and $x \odot y := x + y$. From an algebraic geometric point of view, algebraic varieties over a field with non-archimedean valuation are replaced by polyhedral complexes, thereby retaining much of the information about the original varieties. From the point of view of complex geometry, the geometric combinatorial structure of tropical varieties is a maximal degeneration of a complex structure on a manifold.

The tropical transition from the objects of algebraic geometry to the polyhedral realm opens classical problems to a completely new set of techniques, and has already led to remarkable results in Enumerative Algebraic Geometry, Symplectic Geometry, Dynamical Systems and Computational Commutative Algebra, among other fields, and to applications in Algebraic Statistics, Mathematical Biology, and Statistical Physics. Recent tropical papers explore connections to Low-dimensional Topology, Number Theory, Representation Theory, Optimization, Enumerative Combinatorics, Stochastic Processes, Random Matrix Theory, and Mathematical Physics.

The semester program at MSRI was the first major research program at a mathematics institute devoted entirely to Tropical Geometry. Preceded by a number of conferences, workshops and summer schools at major research centers around the world, the program was the culmination point of the vivid activities in this newly emerging field, and will be a milestone on its way to a recognized discipline that straddles Algebra, Analysis, Combinatorics and Geometry.

2. Participants

The response to our program from the emerging tropical community was enthusiastic. Six of eight research professors were in residence for the full duration of the program as were all the four organizers (research professors: Vladimir Berkovich, Alicia Dickenstein, Andreas Gathmann, Mark Gross, Viatcheslav Kharlamov, Mikael Passare, Oleg Viro, Annette Werner). Together with 23 research members, most of them staying for several months, they shaped an exciting program and helped provide mentoring for the unusually high numbers of postdocs (16) and program associates (9). With a view towards diversity issues, let us mention that 2 out of 8 research professors in our program were women (25%), as were 5 out of 23 research members (22%), and 5 out of 16 postdocs (31%).

3. Organizatorial Structure

Besides two introductory workshops and two topical workshops on which we comment below, a number of seminars and working groups were run throughout the program. Notably, the Tropical Colloquium and the Tropical Seminar (both organized by research professors Alicia Dickenstein and Mark Gross) provided opportunities for program participants to report on their latest progress. A weekly postdoc seminar run jointly with the Symplectic and Contact Geometry and Topology program provided a forum for postdocs to talk about their work and interests. The postdoc seminar was followed by an MSRI sponsored pizza lunch which provided ample opportunity for informal conversation and exchange. There were also a number of regular graduate student activities on which we report in the respective section below.

4. Synergistic Activities

There was ample interaction with the Symplectic and Contact Geometry and Topology program (SCGT) run in parallel at MSRI in the fall of 2009. This happened both on the informal level of conversations and collaborations (see our report on research developments below) and on a more formal level. Regarding the latter, let us here mention the joint postdoc seminar, the mini-course by Denis Auroux (a member of the SCGT program) in our introductory workshop, and the postdoc position for Brett Parker shared by both programs.

Another most visible event was the bi-weekly MSRI Evans Lecture Series organized in collaboration with the SCGT program. The talks contributed by the Tropical Geometry program were the following:

- Grigory Mikhalkin: *Tropical versus real geometry*, Oct 12
- Annette Werner: *Buildings and Berkovich spaces*, Oct 26
- Sam Payne: *Nonarchimedean algebraic geometry*, Nov 9
- Mark Gross: *A glimpse into the heart of mirror symmetry*, Nov 23

5. Workshops

There were four workshops held at MSRI in connection with our program. The beginning was marked by the two introductory workshops organized back-to-back in late August:

Connections for Women: Tropical Geometry, Aug 22/23, 2009, organized by Alicia Dickenstein and Eva-Maria Feichtner.

With a view on the many graduate students and young mathematicians attending, the focus of this introductory event were two short-courses (two 1h lectures each, interconnected with exercises and informal discussion sessions):

- Federico Ardila: *Linearity in the tropics*
- Hannah Markwig: *Counting tropical plane curves.*

The short-courses were complemented by five research lectures

- Josephine Yu: *Tropical varieties, elimination, and mixed fiber polytopes*
- Lucia Lopez de Medrano: *Tropical inflection points of tropical planar curves*
- Annette Werner: *Buildings and tropical geometry*
- Marianne Akian: *Tropical linear independence and symmetrization of the tropical semi-ring*
- Lauren Williams: *The tropical Grassmannian and its positive part*

There were also three short communications (by Thomas Markwig, Kirsten Schmitz, and Anne Shiu), and a panel discussion on career issues for female mathematicians.

Introductory Workshop: Tropical Geometry, Aug 24–28, 2009, organized by Eva-Maria Feichtner, Ilia Itenberg, Grisha Mikhalkin and Bernd Sturmfels.

Paying tribute to the introductory character of the event, the main emphasis of this workshop was on five mini-courses that were designed to present the various approaches and viewpoints on tropical geometry and lay out the scene for the research work of the upcoming semester. Each minicourse consisted of three 1h-lectures.

- Denis Auroux: *Some tropical aspects of mirror symmetry*
- Ilia Itenberg: *Real aspects of tropical geometry*
- Diane Maclagan: *Introduction to tropical algebraic geometry*
- Mikael Passare: *Amoebas and co-amoebas*
- Evgeni Tevelev: *Tropical elimination theory.*

The mini-courses were complemented by five research lectures:

- Grigory Mikhalkin: *Basic tropical notions: varieties and maps*
- Jean-Jacques Risler: *Real algebraic geometry, tropical geometry and total curvature*
- Alicia Dickenstein: *A naive approach to the implicitization of rational varieties using tropical tools*
- Mohammed Abouzaid: *Symplectic perspectives on tropical geometry*
- Mark Gross: *Towards canonical theta functions for Calabi-Yaus.*

Two topical workshops followed later during the program:

Tropical Geometry in Combinatorics and Algebra, Oct 12–16, 2009, organized by Federico Ardila, David Speyer, Jenia Tevelev and Lauren Williams.

The focus of the workshop was on tropical methods in combinatorics and algebra, e.g., in combinatorial linear algebra, combinatorial representation theory, and algebraic statistics. Here is the list of research lectures in chronological order:

- Sam Payne: *Topology of compactified tropicalizations*
- Alex Esterov: *Newton polyhedra and Minkowski integrals*
- Eric Katz: *Realization spaces for tropical Varieties*
- Arkady Berenstein: *Geometric crystals and tropical combinatorics*

- Gleb Koshevoy: *Bases of tropical Plucker functions, wirings, tilings and Leclerc-Zelevinsky conjectures*
- Filip Cools: *Tropical geometry and dissimilarity vectors of trees*
- Daniele Alessandrini: *Tropicalization of Teichmuller spaces*
- Walter Gubler: *Tropical analytic geometry and the Bogomolov conjecture*
- Josephine Yu: *Linear systems on tropical curves*
- Diane Maclagan: *Tropical bounds on effective cycles*
- Matthew Baker: *Metric properties of the tropical Abel-Jacobi map*
- Filippo Viviani: *On the tropical Torelli map*
- Sergey Fomin: *Enumeration of plane curves and labeled floor diagrams*
- Michael Joswig: *Coarse tropical convexity and cellular resolutions*
- Thorsten Theobald: *Combinatorics and genus of tropical intersections and Ehrhart theory*
- Alex Fink: *Tropical cycles and Chow polytopes*
- Annette Werner: *Buildings and tropical geometry*

Tropical Structures in Geometry and Physics, Nov 30 – Dec 4, 2009, organized by Mark Gross, Kentaro Hori, Viatcheslav Kharlamov and Richard Kenyon.

The focus of this workshop was on applications of tropical geometry to as diverse areas as enumerative geometry, symplectic field theory, mirror symmetry, dimer models/random surfaces, amoebas and algas, instantons, and cluster varieties. Here is the list of research lectures in chronological order:

- Allen Knutson: *Reduced degenerations and Frobenius splitting*
- Lauren Williams: *Teichmuller space, cluster algebras from surfaces, and the positivity conjecture*
- David Speyer: *Determinental hypersurfaces, convex polynomials and tropical geometry*
- Mikael Passare: *Some aspects of discriminantal (co)amoebas*
- Oleg Viro: *Complex tropical geometry*
- Ilia Zharkov: *Tropical (p,q)-classes of Lagrangian type*
- Eugenii Shustin: *Real tropical enumerative invariants*
- Rares Rasdeaconu: *Relative open Gromov-Witten invariants*
- Erwan Brugallé: *Realizability of superabundant tropical curves*
- Hannah Markwig: *Tropical descendant Gromov-Witten invariants*
- Daniele Alessandrini: *On the compactification of the parameter space of convex projective structures*
- Mohammed Abouzaid: *Towards a tropical Fukaya category*
- Daniel Krefl: *Real enumerative geometry via the topological string*
- Amihay Hanany: *(p, q)-webs and their applications in string theory*
- Barak Kol: *Tropical geometry and (p, q)-webs*
- Mina Aganagic: *Tropical Geometry and the Topological String*
- Grigory Litvinov: *Dequantization and tropical structures in classical mechanics and classical geometry*
- Stephan Tillmann: *The Hilbert geometry of the n-simplex*
- Paul Hacking: *Smoothing surface singularities via mirror symmetry*
- Janko Boehm: *Calabi-Yau mirrors via tropical geometry*
- Brett Parker: *Tropical curves and Gromov Witten invariants*

6. Research Developments

Here is a sample of the many new research developments that emerged during the program:

1. Mohammed Abouzaid, Mark Gross and Bernd Siebert have started their work on the *tropical version of the Fukaya category.* This project mends tropical curve and tropical-looking gradient flows that appeared in the work of Fukaya and Oh. The outcome allows to compute not only the number of holomorphic disks, but to incorporate the information about their area which is crucial for computing the superpotential.

2. Vladimir Berkovich worked on the development of *analytic geometry over the field of one element.* This provides a systematic new approach to the analytification of algebraic varieties, and its connection to tropical geometry.

3. Erwan Brugallé and Grigory Mikhalkin have worked on *realizability of superabundant tropical curves* extending the realizability criterion found by David Speyer for elliptic curves. They have used tropical modification to extend Speyer's criterion to arbitrary genus case.

4. Erwan Brugallé and Lucia Lopez de Medrano have used tropical modifications to locate (and relate to the real geometry case) *tropical singularities*, in particular tropical inflection points.

5. Dustin Cartwright, Mathias Häbich, Bernd Sturmfels and Annette Werner started to write a joint paper on *Mustafin varieties.* Such a variety is a degeneration of projective space induced by a point configuration in a Bruhat-Tits building. The special fiber is reduced and Cohen-Macaulay, and its irreducible components form interesting combinatorial patterns. For configurations that lie in one apartment, these patterns are regular mixed subdivisions of scaled simplices, and the Mustafin variety is a twisted Veronese variety built from such a subdivision. This is the connection to tropical and toric geometry. For general configurations, the irreducible components of the special fiber are rational varieties, and any blow-up of projective space along a linear subspace arrangement can arise. A detailed study of Mustafin varieties was undertaken for configurations in the Bruhat-Tits tree of $PGL(2)$ and for triangles in the building of $PGL(3)$.

6. Jan Draisma has begun to develop a theory of *tropical reparameterizations.* Given a classical polynomial map $f : \mathbb{A}^m \to \mathbb{A}^n$ between affine spaces parameterizing a variety $X = \mathrm{im}(f)$, the aim is to construct a coordinate change $a : \mathbb{A}^p \to \mathbb{A}^n$ such that the composition $f \circ a$ tropicalizes naively (that is, by replacing $+$ by *min* and $\times$ by $+$) to a tropical polynomial map whose image is all of $\mathrm{trop}(X)$. This has the appealing interpretation that trop(X) can be "folded" from a piece of p-dimensional paper. At MSRI, Draisma systematically classified known examples where this is the case, and he proved the existence of coordinate changes that are good locally.

7. Anton Dochtermann, Michael Joswig and Raman Sanyal completed a paper on *tropical types and associated cellular resolutions.* An arrangement of tropical hyperplanes in the tropical torus leads to a notion of 'type' data for points, with the underlying unlabeled arrangement giving rise to 'coarse type'. The decomposition of the tropical torus induced by types gives rise to minimal cocellular resolutions of certain associated monomial ideals. Via the Cayley trick from geometric combinatorics this also yields cellular resolutions supported on mixed subdivisions of dilated simplices, extending previously known constructions. Moreover, the methods developed lead to an algebraic algorithm for computing the facial structure of arbitrary tropical complexes.

8. Andreas Gathmann and his students from Kaiserslautern continued their research on *tropical enumerative geometry.* In algebraic geometry, enumerative problems are usually studied by constructing moduli spaces of curves or stable maps to some variety. In the tropical world the corresponding spaces have only been constructed so far for rational curves in a real vector space.

While at MSRI, Gathmann extended the construction of tropical moduli spaces to cases of curves of higher genus or whose ambient spaces are more general tropical varieties than vector spaces.

9. Ilia Itenberg, Viatcheslav Kharlamov and Eugenii Shustin worked on a paper devoted to Welschinger invariants of small Del Pezzo surfaces. It contains a recursive formula for purely real Welschinger invariants of the following real Del Pezzo surfaces: the projective plane blown up at q real and $s \leq 1$ pairs of conjugate imaginary points, where $q + 2s \leq 5$, and the real quadric blown up at $s \leq 1$ pairs of conjugate imaginary points and having non-empty real part. The formula is similar to Vakil's recursive formula for Gromov-Witten invariants of these surfaces and generalizes the recursive formula for purely real Welschinger invariants of real toric Del Pezzo surfaces (the latter formula was obtained earlier by Itenberg, Kharlamov and Shustin). The consequences of the formula include the positivity of the Welschinger invariants under consideration and their logarithmic asymptotic equivalence to genus zero Gromov-Witten invariants.

10. Ilia Itenberg, Grigory Mikhalkin and Ilia Zharkov have advanced on a project on tropical homology. The outcome of this project is a definition of homology (and cohomology) groups enhanced with the tropical Picard-Fuchs operator responsible for Schmid's Mixed Hodge Structure of the degeneration. These tropical objects are expected to match with the corresponding classical objects in the case when the tropical manifold (smooth in the coarse sense) comes as a tropical limit of a 1-parametric family of complex manifolds. Furthermore the resulting framework allows to dualize the tropical set-up (according to the Mirror Symmetry principles) to get a different type of homology groups conjecturally responsible for deformations. A particularly attractive feature is similarity of the geometric object corresponding to the Picard-Fuchs operator (tropical wave) with the tropical hyperplane section.

11. Eric Katz and Sam Payne finished an article on *realization spaces for tropical fans.* They introduced a moduli functor for varieties whose tropicalization realizes a given weighted fan and showed that this functor is an algebraic space in general, and is represented by a scheme of finite type when the associated toric variety is quasiprojective. They also studied the geometry of tropical realization spaces for the matroid fans studied by Ardila and Klivans, and show that the tropical realization space of a matroid fan is a torus torsor over the realization space of the matroid. One consequence is that these tropical realization spaces satisfy Murphy's Law.

12. Ludmil Katzarkov, Grigory Mikhalkin and Ilia Zharkov worked on *tropical Jacobians* in higher dimension (in particular, intermediate Jacobians) and Prymians. The outcome of this ongoing project was a refinement of the intermediate Jacobian in the tropical case and connection between this refinement and the tropical wave corresponding to the Picard-Fuchs operator.

13. Diane Maclagan worked on the *tropical inverse problem.* Here the starting point is the fact that every tropical curve (meaning a weighted balanced one-dimensional rational polyhedral complex) is the tropicalization of a curve in the torus, and the tropical inverse problem asks for which tropical complexes this is the case. She studied various variants of this question, and she explored its relevance to birational geometry.

14. Hannah Markwig, Thomas Markwig and Eugenii Shustin completed a paper, titled *Tropical curves with a singularity in a fixed point*, which concerns families of curves with a singularity in a fixed point. The tropicalization of such a family is a linear tropical variety. They describe its maximal dimensional cones using results on linear tropical varieties due to Ardila–Klivans and Feichtner–Sturmfels. They show that a singularity tropicalises either to a vertex of higher valence or of higher multiplicity, or to an edge of higher weight. They also classify maximal dimensional types of singular tropical curves. For those, the singularity is either a crossing of

two edges, or a 3-valent vertex of multiplicity 3, or a point on an edge of weight 2 whose distances to the neighbouring vertices satisfy a certain metric condition.

7. Postdocs

A total number of 16 postdocs were affiliated with our program. Seven of them were sponsored as MSRI postdocs, others had (partial) member funding or were supported by outside sources. We took special care in assigning senior mentors to our postdocs for the duration of the program. Our aim was to avoid the obvious matchings, but rather to assign mentors in a way that could introduce new aspects, topics, and contacts to the postdoc's work. We received a wealth of positive feed-back concerning the mentoring program, which led to many new collaborations.

We here provide brief reports on our postdoc's activities in their own words:

Tristram Bogart

PhD: University of Washington, 2007
"Problems in computational algebra and integer programming"
Previous affiliations: Coleman postdoctoral fellow, Queen's University, Canada
Professional Placement: Coleman postdoctoral fellow, Queen's University (spring 2010);
NSF institutes postdoctoral fellow, San Francisco State University (2010-11)
Mentor at MSRI: Federico Ardila

Tristram Bogart continued to work on a project with Erwan Brugallé (at MSRI all semester) and Ethan Cotterill (at MSRI for the first 8 weeks) on tropical rational curves on general tropical hypersurfaces. Also, he began a project with Eric Katz (another MSRI postdoc) on local obstructions to lifting tropical curves, and discussed a potential future project involving the tropical positive Grassmannian with his mentor Federico Ardila, who will also be his mentor at SFSU next year.

"It was extremely useful for me to have so many researchers in tropical geometry in one place, as it gave me a much improved idea of the techniques that are currently being employed. I would probably not have begun the project with Katz anywhere else. Just organizing and reviewing seminar notes from the MSRI semester will be an important task for me in the coming semester."

Erwan Brugallé

PhD: Rennes University, 2004
"Real algebraic curves and real pseudoholomorphic curves in ruled surfaces"
Previous affiliations: Pierre and Marie Curie University
Professional Placement: Pierre and Marie Curie University
Mentor at MSRI: Mikael Passare

"During my postdoc at MSRI, I could carry out ongoing collaborations with other members of the Tropical Geometry semester (Grigory Mikhalkin, Lucia Lopez de Medrano, Hannah Markwig, Ethan Cotterill and Tristram Bogart), as well as starting new ones (with Josephine Yu and Ilia Zharkov, with Omid Amini). In parallel, I met many people and established many new contacts that will certainly be fruitful in the near future. I had the opportunity to learn a lot from these new contacts and our discussions.

The connection between the two parallel semesters Tropical Geometry and Symplectic Geometry was very good, as these two areas of mathematics have many deep connections. I benefited as well from many discussion with people in this semester.

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In conclusion, my postdoc at MSRI has been very profitable for me: it enlarged my mathematical panorama, I could finish ongoing works, start new ones, and make new contacts. I'm looking forward to a next stay at MSRI!"

Eric Katz

PhD: Stanford, 2004
"A Formalism for Relative Gromov-Witten Invariants"
Previous affiliations: Duke University, Assistant Research Professor;
U Texas Austin, Lecturer/RTG Postdoc
Professional Placement: NSF Institute Postdoc, MSRI
Mentor at MSRI: Dmitry Feichtner-Kozlov

Eric Katz finished an article joint with Sam Payne on realization spaces for tropical fans (see above: Research Developments, 11). He has a draft paper completed with Alan Stapledon on connections between tropical geometry and limiting mixed Hodge structures of degenerations of complex varieties. Moreover, he started projects with Christian Haase, Gregg Musiker and Alan Stapledon on chip-firing on simplicial complexes, and with Tristram Bogart on local obstructions to lifting tropical curves.

Lucia Lopez de Medrano

PhD: Université de Paris VI, 2007
"Courbure totale des hypersurfaces algebriques reelles et patchwork"
Previous affiliations: Universidad Nacional Autonoma de Mexico. Postdoc.
Professional Placement: Universidad Nacional Autonoma de Mexico. Postdoc.
Mentor at MSRI: Bernd Sturmfels

"I mainly worked on the joint project with Erwan Brugallé about Tropical inflection points. This project started in June when Erwan visited me in Mexico. In the MSRI, we finished all the cases. I wrote a first version of the paper in the MSRI. I presented this work in the first workshop and in the postdoc seminar.

I also finished the corrections of two papers: "Puiseux power series solutions for systems equations" (joint work with Fuensanta Aroca and Giovanna Illardi) and "Recursive formulas for Welschinger invariants of the projective plane" (joint work with Aubin Arroyo and Erwan Brugallé).

I discused with Mikael Passare about a future project.

In the MSRI, I met a lot of people working in Tropical Geometry and I learned about their present work and the techniques they use. I'm sure this will be very usefull for futures projects and collaborations. I already invited some of them to visited me in Mexico to collaborate with our Tropical team.

My son Mahigan was born on December 11th, 2009."

Christoffer Manon

PhD: University of Maryland, 2009
"Presentations of Semigroup Algebras of Weighted Trees"
Previous affiliations: n/a
Professional Placement: UC Berkeley, NSF postdoc
Mentor at MSRI: David Eisenbud

I worked on the combinatorial commutative algebra of the Cox ring of the moduli stack of parabolic principal bundles on a projective curve. In addition to setting up machinery to study presentations of these rings, I also investigated a related tropical variety and cluster algebra.

Gregg Musiker

PhD: UC San Diego, 2007
"A Combinatorial Comparison of Elliptic Curves and Critical Groups of Graphs"
Previous affiliations: MIT, NSF Postdoctoral Fellow and Instructor of Applied Mathematics
Professional Placement: MIT, NSF Postdoctoral Fellow and Instructor of Applied Mathematics
Mentor at MSRI: Eva Feichtner

Gregg Musiker was one of the organizers and participants in the weekly working/reading group on chip-firing and connections to tropical geometry, where he learned new techniques including the Specialization Lemma of Matt Baker, techniques from Brill-Noether theory, and the relationship with the tropical lifting problem.

He submitted one paper ("Linear Systems on Tropical Curves" with Christian Haase and Josephine Yu), finalized one accepted paper ("Cluster expansion formulas and perfect matchings" with Ralf Schiffler) and lists four on-going projects, mostly with new contacts: "Chip-firing on simplicial complexes" with Christian Haase, Eric Katz, and Alan Stapledon, "Description of linear equivalent classes of certain ranks" with Ethan Cotterill, "Cluster algebras of surfaces II" with Ralf Schiffler and Lauren Williams, and "Zonotopes and reduced divisors" with Federico Ardila and Ilia Zharkov.

Gregg gave several talks in the area, introducing new audiences to his work (MSRI Postdoc Seminar, MSRI Tropical Geometry Seminar, UC Berkeley Representation Theory, Geometry, and Combinatorics Seminar, San Francisco State University Algebra, Geometry, and Combinatorics Seminar Stanford University) and gave seminar and colloquia talks at several universities, including University of Washington, MIT, Texas A&M, Arizona State University, UC San Diego, and University of Southern California. Moreover, he spoke at the AMS Eastern Sectional hosted by Penn State.

He puts a particular emphasis on the many new contacts he made at MSRI, including Florian Block, Erwan Brugalle, Tristram Bogart, Ethan Cotterill, Satyan Devadoss, Christian Haase, Eric Katz, Viatcheslav Kharlamov, Sam Payne and Ilia Zharkov.

Benjamin Nill

PhD: University of Tübingen, Germany, 2007
"Gorenstein toric Fano varieties"
Previous affiliations: FU Berlin, postdoc (German Science Foundation)
Professional Placement: University of Georgia, postdoc
Mentor at MSRI: Ilia Itenberg

"At the MSRI I talked with several people, many of them I never had collaborated with before:

-with Alan Stapledon, an all-term postdoc in the Tropical Geometry program at MSRI, and Raman Sanyal, a postdoc at UC Berkeley. We discussed how a mixed version of Ehrhart theory might look like. This was motivated by a recent paper of Reinhard Steffens and Thorsten Theobald on tropical intersections. It was especially helpful that Theobald gave a talk at one of the MSRI workshops.

-with Christian Haase, who stayed as a member of the Tropical Geometry program at MSRI for about one month. We proceeded with a joint project with Sandra Di Rocco about a polyhedral formulation of the adjunction theory of toric varieties.

-with Alicia Dickenstein, an all-term member of the Tropical Geometry program at MSRI. We managed to clarify completely the relation between the combinatorial notion of the codegree of a smooth lattice polytope and the dual defect of the associated polarized toric manifold. This has new implications in the adjunction theory of toric manifolds. We hope to have a preprint finished shortly.

-with Christopher Severs, an all-term postdoc in the Complementary Program at MSRI. We discussed some open combinatorial problems related to the Stanley depth in combinatorial commutative algebra that came up in a recent paper of myself with Kathrin Vorwerk.

-with Janko Boehm, a postdoc at UC Berkeley. We talked about several aspects of toric and tropical mirror symmetry constructions. In particular, can the stringy E-function of a complete intersection Calabi-Yau in a toric variety the transverse faces of the associated Minkowski sum? Can one generalize the duality of reflexive Gorenstein cones such that also the case of Pfaffians is covered?

Apart from these projects, I ventured further into tropical geometry, for which the MSRI program provided an outstanding environment. I attended all four workshops at MSRI of the Tropical Geometry program, as well as the Graduate student seminar, the Tropical Seminar, and the Tropical Colloquium. I took also advantage of the UC Berkeley seminar in Discrete Mathematics and of the lecture on Mirror Symmetry by Denis Auroux. I liked especially the joint Postdoc Seminar at the MSRI which also included talks of symplectic geometers.

Moreover, in November I gave a talk in the discrete math seminar at UC Davis with the title "Hollow Lattice Polytopes". I also used the travel funding by the MSRI to attend the week-long Workshop on Combinatorial Geometry at the IPAM at Los Angeles.

Finally, I wrote two referee reports (one for the proceedings of the CBMS Conference on Tropical Geometry and Mirror Symmetry and one for Discrete and Computational Geometry). Since one of the authors stayed at MSRI for a workshop in the Tropical Geometry program, I could manage to get more insight in that work and stimulate further research on his side.

Overall, the MSRI gave me ample time to start new projects and a unique opportunity to learn the state of the art in tropical geometry, from which I will surely benefit in the future.

Lisa Nilsson

PhD: 2009, Stockholm University
"Amoebas, Discriminants, and Hypergeometric Functions"
Previous affiliations: n/a
Professional Placement: Institute Mittag-Leffler, Sweden
Mentor at MSRI: Bernd Sturmfels

Lisa Nilsson finished a joint paper with research professor Mikael Passare on discriminantal coamoebas in dimension two and reported on the results in the postdoc seminar.

Also, she pursued an ongoing project with Elisabth Wulcan from U Michigan on higher dimensional discriminantal coamoebas and started a new project with Felipe Rincon, a graduate student at UC Berkeley, and Bernd Sturmfels on characterizing coamoebas of Grassmannians.

Mounir Nisse

PhD: University Paris 6, 2009
"On the geometry of amoebas and coamoebas of complex hypersurfaces"
Previous affiliations: n/a
Professional Placement: University Paris 6
Mentor at MSRI: Andreas Gathmann

"(i) Joint work with F. Sottile : "Complex and non-Archimedean Coamoebas".

We define a new object (the analogous of the logarithmic limit set) for any algebraic variety which we call Phase limit set, and we prove some analogous combinatorial properties of this object similar to that of the logarithmic limit set. More precisely we have the following:

The phase limit set of a complex algebraic variety contains an arrangement of k-torus where their number depends on that of the $(k-1)$-cells of the logarithmic limit set counted with their multiplicities. The goal of this section, is to prove the following theorem, and give a description of the phase limit set of an algebraic variety.

Theorem: Let V be an algebraic variety of dimension k in $(\mathbb{C}^*)^n$. Let $co\mathcal{A}$ be its coamoeba and $\mathcal{P}^\infty(V)$ its phase limit set. Then $\overline{co\mathcal{A}} = co\mathcal{A} \cup \mathcal{P}^\infty(V)$, where $\overline{co\mathcal{A}}$ denotes the closure of $co\mathcal{A}$ in the universal covering of the real torus. Moreover, $\mathcal{P}^\infty(V)$ is the union of some arrangement $\mathcal{H}(V)$ of k-torus and the coamoebas of some complex algebraic varieties of dimension l with $l \leq k-1$.

We introduced the notion of non Archimedean coamoebas and we prove some geometric and combinatorial properties of this object.

(ii) Joint work with P. Johansson and M. Passare : "Amoebas and coamoebas of linear spaces".

We give a complete description of the amoebas and coamoebas of complex linear spaces. A lot of example are given (the line in $\mathbb{C}^3$, the plane in $\mathbb{C}^4$, and others).

(iii) "Some Geometric and Topological description of the amoeba and the coamoeba of curves in $\mathbb{C}^n$ for $n \geq 2$", I give the analogous of the "spine" of the amoeba of curves in $\mathbb{C}^n$. Moreover, I prove for certain curves their amoeba is always contained in some variety M diffeomorphic to $\mathbb{R}^2$, and $M \subset \mathbb{R}^n$. If the curve is complicated (I mean topologically, for example its linking number with itself is different than zero, then the surface M is much more complicated, I mean it is not contractible).

(iv) I have a discussion with Annette Werner on the generalization of these works to an algebraic variety over a field k with valuation (for example $\mathbb{Q}_p$). This is one of my future project. In this case the analogous of the argument is an object which lives in a cantorean set, which is much more complicated.

The two first works are finished, the third one I'm working in this time and the fourth one its a project with a lot of ideas of Annette and me.

Thank you for all, this meeting allowed me to see and discuss with specialists that I could never see elsewhere. It also allowed me to finish some projects and have other. So, thanks for all the organizers of this program and thanks for MSRI!"

Brett Parker

PhD: Stanford, 2005
"Holomorphic curves in Lagrangian torus fibrations"
Previous affiliations: MIT, Moore instructor; Berkeley, Visiting assistant professor
Professional Placement: MSRI, symplectic program postdoc
Mentor at MSRI: Yakov Eliashberg and Mark Gross

"I was working on the relationship between Gromov Witten invariants and tropical curves in a more general context than the usual tropical setup. My work could be regarded as studying geometry over the semiring obtained by taking the leading term of Puisseaux series. (This is closest to the approach to tropical geometry involving log geometry taken by Gross and Siebert). By participating in the tropical program, I learned more about the other approaches to tropical geometry and the problems which they address. Of more direct application to my work, I learned about the relationship between tropical curves and descendant gromov witten invariants and learned some more about the relationship between mirror symmetry and tropical geometry. I think that I also managed to convince some participants of the value of my different approach to tropical geometry."

Sam Payne

PhD: U Michigan, 2006
"Toric vector bundles"
Previous affiliations: Stanford, visiting assistant professor;
Clay Mathematics Institute, postdoctoral research fellow
Professional Placement: Clay Mathematics Institute, postdoctoral research fellow
Mentor at MSRI: Ilia Itenberg

Sam Payne worked with Brian Osserman on tropical lifting theorems and with Filip Cools, Jan Draisma, and Elina Robeva on tropical Brill-Noether theory. Both of these were new collaborations.

Alan Stapledon

PhD: University of Michigan, 2009
"The geometry and combinatorics of Ehrhart δ-vectors"
Previous affiliations: n/a
Professional Placement: University of British Columbia, Postdoc
Mentor at MSRI: Viatcheslav Kharlamov

"I began my semester at MSRI with a background in toric geometry, but with little exposure to tropical geometry. Through my participation in the semester at MSRI, I was able to obtain an overview of tropical geometry, meet a large number of people in the area, and, towards the end of the semester, start producing interesting results in the field.

My most interesting new work which arose from the semester establishes a connection between tropical geometry and limiting mixed Hodge structures of degenerations of complex varieties. This is a joint project with Eric Katz, also a postdoc at MSRI who I first met this semester. We currently have a draft completed titled 'Limiting mixed Hodge structures via tropical geometry' which we hope to be an the arXiv sometime next semester.

Other projects that I have started at MSRI involve studying higher dimensional chip-firing with Eric Katz, Gregg Musiker and Christian Haase, and studying mixed Ehrhart theory with Benjamin Nill and Raman Sanyal. Gregg Musiker was a postdoc at MSRI who I met for the first time this semester.

While at MSRI, I was able to work on a project with Matthias Beck and Christian Haase on classifying Ehrhart polynomials of low-dimensional polytopes. This work was initiated prior to the semester at MSRI and does not involve tropical geometry, but, by being together in the Berkeley area, we were able to make significant progress on this project. We are currently typing up a draft of this paper.

During my time at MSRI, I was also able to complete a project with Dave Anderson establishing a connection between the geometry of arc spaces and equivariant cohomology. This work does not involve tropical geometry, and was a focus of mine before the semester. The paper titled 'Arc spaces and equivariant cohomology' was placed on the arXiv and submitted in October 2009."

Luis Felipe Tabera

PhD: University of Cantabria / University of Rennes I, 2007
"Two tools in algebraic geometry: Construction of configurations in tropical geometry and hypercircles for the simplification of parametric curves"
Previous affiliations: University of Barcelona, Associate professor (September 2007 - December 2007); IMDEA Mathematics (Spain), Postdoctoral researcher (January 2008 - December 2008); University of Cantabria, Postdoctoral Researcher (January 2009 - April 2009); UC Berkeley, Postdoctoral Researcher (May 2009 - November 2009)
Professional Placement: University of Cantabria, Spain, Associate professor
Mentor at MSRI: Grisha Mikhalkin

"I have been working mainly on the notion of singular tropical hypersurfaces, trying to define a tropical notion of singularity that is compatible with the algebraic notion via tropicalization. I have made contact with other people interested in these notions, E. Brugallé, A. Dickenstein and H. Markwig.

In a joint work with A. Dickenstein we have succesfully developped a theory of partial derivatives that allow to define and compute a singular point inside a tropical hypersurface."

Lauren Williams

PhD: MIT, 2005
"Combinatorial aspects of total positivity"
Previous affiliations: NSF postdoc at UC Berkeley (05/06),
Benjamin Peirce Asst prof at Harvard (06-09),
Viterbi Endowed postdoc at MSRI (Spring 08)
Professional Placement: UC Berkeley, assistant professor
Mentor at MSRI: Grisha Mikhalkin

While at MSRI I continued thinking about total positivity and its connections to tropical geometry. I also investigated the connections between Teichmuller theory and tropical geometry, via cluster algebras and cluster varieties. Gregg Musiker and I continued our work on the cluster algebras associated to surfaces. But probably the most beneficial aspects of my postdoc at MSRI was establishing new contacts. I had several very interesting discussions with Mark Gross about mirror symmetry and possible connections to cluster algebras. I also met several times with my mentor Grisha Mikhalkin, who explained to me the Thurston compactification of Teichmuller space. And I met Rick Kenyon and had several very interesting discussions with him, which may lead to a joint project.

JOSEPHINE YU

PhD: UC Berkeley, 2007
"Combinatorial Aspects of Tropical Geometry"
Previous affiliations: MIT
Professional Placement: Georgia Institute of Technology
Mentor at MSRI: Annette Werner

"At MSRI, I completed or made substantial progress on three papers that I started before the semester:

(1) Linear Systems on Tropical Curves (with Christian Haase and Gregg Musiker)
(2) Implicitization Challange for Binary Factor Analysis (with Maria Angelica Cueto and Enrique A. Tobis)
(3) On a Parameterization of Positive Semidefinite Matrices with Zeros (with Mathias Drton)

More importantly, I started new projects with new collaborators:

(1) Computing Mixed Fiber Polytopes (with Anders Jensen)
(2) Tropically Convex Sets in Buildings (with Annette Werner)

Moreover, I had many discussions with other participants, which generated new ideas for me, and I am confident that they will turn into very interesting projects. For example, I learned a lot about algebraic curves and tropical modification from Erwan Brugalle and Ethan Cotterill. These directions and techniques are new to me and will be very useful. The MSRI semester was by far the most productive semester for me, even in comparison with my time spent at major research departments like those at UC Berkeley and MIT. The environment at MSRI fosters collaboration and discussions. The concentration of mathematicians, especially my peers, who are excited about similar topics is invaluable."

8. GRADUATE STUDENTS

A characteristic feature of our program was the strong and active participation of graduate students. This lively group was comprised of students from UC Berkeley and San Francisco State University, as well as students from other institutions who came to MSRI together with their doctoral advisors. These had the status of *program associates.* A weekly graduate student seminar was organized jointly by Alex Fink (UC Berkeley) and Franziska Schröter (U Göttingen). The following research lectures were presented by graduate students in that seminar:

- Mathias Häbich (Franfurt, Germany): *Degenerations of projective space induced by an affine building*
- Felipe Rincon (UC Berkeley): *Tropical isotropic linear spaces and Delta-matroid subdivisions*
- Benjamin Iriarte (San Francisco State University): *Phylogenetic trees and the tropical Grassmannian*
- Lars Allermann (Kaiserslautern, Germany): *Introduction to tropical intersection theory I*
- Kristen Freeman (San Francisco State University): *Tropical oriented matroids and triangulations of products of simplices*
- Johannes Rau (Kaiserslautern, Germany): *Tropical intersection theory II*
- Florian Block (U Michigan): *Computing node polynomials for plane curves*
- José Rodriguez (U Texas): *Bounding Belyi polynomials and their relation to dessins d'enfants*

- Kristin Shaw (U Toronto, Canada): *Tropical intersections on matroidal fans via modification*
- Angelica Cueto (UC Berkeley): *An implicitization challenge in binary factor analysis*
- Petter Johansson (Stockholm Univ., Sweden): *Coamoebas with multiplicity*
- Melody Chan (UC Berkeley): *The* 4×4*-minors of a* $5 \times n$*-matrix are a tropical basis*
- Henning Meyer (Kaiserslautern, Germany): *Tropical intersection theory on compact toric varieties*

In addition to the graduate student seminar, there was a more informal *"What-Is" Seminar* organized by Florian Block, Kristin Shaw and Bernd Sturmfels. That seminar offered a forum for graduate students and postdocs to interact, and to learn about relevant mathematical concepts.

Here is a sample of tropical research projects undertaken by graduate students at MSRI:

1. Lars Allermann completed an article on *Chern classes of tropical vector bundles*. In that paper he introduces tropical vector bundles, morphisms and rational sections of these bundles and define the pull-back of a tropical vector bundle and of a rational section along a morphism. He uses bounded rational sections of a tropical vector bundle to define the Chern classes of this bundle and proves some basic properties of Chern classes. Finally he gives a complete classification of all vector bundles on an elliptic curve up to isomorphisms.

2. Florian Block worked on *computing node polynomials for plane curves*. Counting algebraic curves with certain prescribed properties is an old problem going back more than 150 years. Block's research is motivated by the following question: How many algebraic plane with a given number of nodes and given degree pass through a sufficient number of generic points? Fomin and Mikhalkin proved that this number is a polynomial (the node polynomial) if the degree is sufficiently large. Using tropical geometry and labeled floor diagrams, Block derived some new node polynomials and some combinatorial results about their structure.

3. Melody Chan and Dustin Cartwright introduced *three notions of tropical rank for symmetric matrices*. These express the tropical rank for symmetric and dissimilarity matrices in terms of minimal decompositions into rank 1 symmetric matrices, star tree matrices, and tree matrices. Their characterize the tropical secant sets of certain nice tropical varieties, including the tropical Grassmannian. In particular, they determine the dimension of each secant set, the convex hull of the variety, and in most cases, the smallest secant set which is equal to the convex hull.

4. Melody Chan also completed a joint research paper with Anders Jensen and Elena Rubei in which she proves that *the 4x4 minors of a 5xn matrix are a tropical basis*. To be precise, they computed the space of 5×5 matrices of tropical rank at most 3 and showed that it coincides with the space of 5×5 matrices of Kapranov rank at most 3. They also showed that the Kapranov rank of every $5 \times n$ matrix equals its tropical rank; equivalently, that the 4×4 minors of a $5 \times n$ matrix form a tropical basis. This answers a question asked by Develin, Santos, and Sturmfels.

5. Angelica Cueto published on article on the *geometry of the restricted Boltzmann machine*, jointly with Jason Morton and Bernd Sturmfels. The restricted Boltzmann machine is a graphical model for binary random variables. Based on a complete bipartite graph separating hidden and observed variables, it is the binary analog to the factor analysis model. She studied this graphical model from the perspectives of algebraic statistics and tropical geometry, starting with the observation that its Zariski closure is a Hadamard power of the first secant variety of the Segre variety of projective lines. One consequence is a dimension formula for the tropicalized model, and this is used to show that the restricted Boltzmann machine is identifiable in many cases. Methods of proof include coding theory and geometry of linear threshold functions

6. Alex Fink was an invited speaker at the research workshop in October, where he presented his project on *tropical cycles and Chow polytopes*. He associates a Chow polytope to any abstract tropical variety in R^n , using a Minkowski sum operation on tropical varieties. This construction generalizes several previously known associations of polyhedra to certain tropical varieties.

7. Benjamin Iriarte wrote a paper on *Phylogenetic trees and the tropical Grassmannian*. One of the main problems in evolutionary biology is that of reconstructing a phylogenetic tree from a DNA sequence alignment of n species. This process is considerably simplified by the distance based approach. In order to really make this approach fruitful, one needs to understand dissimilarity vectors of trees, which leads to the still unsolved problem of characterizing generalized m-dissimilarity vectors of n-trees. It turns out there is a natural relation between these vectors and the corresponding tropical Grassmannian $G_{m,n}$, and this opens the door to tropical geometry as a possible tool to solve the characterization problem. Iriarte identifies the precise relation between these two sets. This resolves a problem stated by Pachter and Speyer in 2003.

8. Kirsten Schmitz, jointly with her advisor Tim Römer, developed a theory of *Generic tropical varieties*. She showed that in the constant coefficient case the generic tropical variety of a graded ideal exists. This can be seen as the analogon to the existence of the generic initial ideal in Groebner basis theory. She also determined the generic tropical variety as a set in general and as a fan for principal ideals, linear ideals and ideals in low dimension.

9. The fruitful interaction with the Symplectic Geometry program was highlighted by the intriguing and geometrically beautiful research project of Nick Sheridan, which relates coamoebas of the hyperplanes with the Fukaya category of the projective planes. Apparently both these things can be described (in some sense) by a single immersed Lagrangian sphere.

10. Cynthia Vinzant wrote a paper on *Real radical initial ideals*. In this work she explored the consequences of an ideal I of real polynomials having a real radical initial ideal, both for the geometry of the real variety of I and as an application to sums of squares representations of polynomials. She showed that if $in_w(I)$ is real radical for a vector w in the tropical variety, then w is in the logarithmic set of the real variety. We also give algebraic sufficient conditions for w to be in the logarithmic limit set of a more general semialgebraic set. If in addition the entries of w are positive, then the corresponding quadratic module is stable. In particular, if $in_w(I)$ is real radical for a positive vector w then the set of sums of squares modulo I is stable. This provides a method for checking the conditions for stability given by Powers and Scheiderer.

The community of graduate students and postdocs formed at MSRI will continue to interact fruitfully in the coming years. One early indication for this was the one-day workshop on Tropical Geometry at TU Berlin in December 2009 which was organized by doctoral students who had only met a few months earlier, at MSRI during the Introductory Workshop in August 2009.

9. Nuggets and Breakthroughs

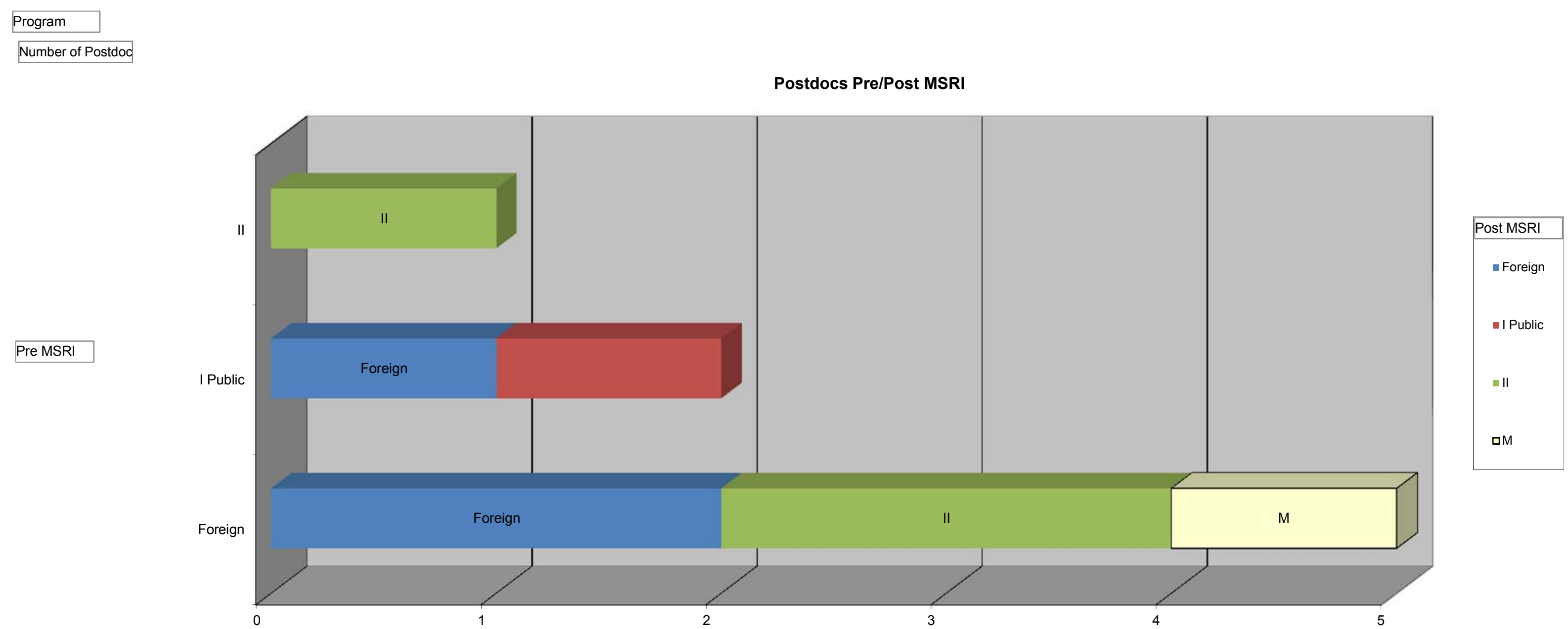
A particularly exciting development was the emerging connection between tropical geometry and number theory, which was highlighted by the work of Matt Baker, Vladimir Berkovich, Walter Gubler and Sam Payne. This was enabled by Payne's remarkable result that Berkovich's analytification of an algebraic variety is the inverse limit of all tropical varieties obtained by choosing a concrete embedding. Walter Gubler solved the longstanding Bogomolov conjecture on equidistribution of points of bounded height on abelian varieties using tropical analytic geometry.

The breakthroughs made during the program and concerning connections between tropical, complex and symplectic geometries are the following ones.

- (Mohammed Abouzaid, Mark Gross, Bernd Siebert) Fusion between tropical curves and the Fukaya-Oh degenerations of Lagrangian disks with the resulting tropical Fukaya category.
- (Ilia Itenberg, Grigory Mikhalkin, Ilia Zharkov) Discovery of "tropical wave" that can be incorporated into the Tropical Homology framework and that comes as a tropical version of the Picard-Fuchs operator.
- (Oleg Viro) Discovery of complex tropical arithmetics and its connection to the phase-tropical world.

Tropical Geometry
Postdoctoral Fellows Pre/Post MSRI
Institution Groups based on AMS classification

				Institute				AMS Groups		
Activity	*Family Name*	*First Name*	*Year Ph.D.*	*Degree*	*Pre MSRI*	*Placement/Post MSRI*	*Position*	*Degree*	*Pre MSRI*	*Post MSRI*
Tropical Geometry	Bogart	Tristram	2007	Univesrity of Washington	Queen's University	San Francisco State University	Postdoc	I Public	Foreign	M
Tropical Geometry	Brugalle	Erwan	2004	Univesrte de Paris VI	Univesrte de Paris VI	Jussieu University - Paris 6	Postdoc	Foreign	Foreign	Foreign
Tropical Geometry	Katz	Eric	2004	Stanford University	Texas A&M University	Texas A&M University	Postdoc	I Private	II	II
Tropical Geometry	Lopez de Medrano	Lucia	2007	University de Paris 7	Universidad Nacional Autonoma de Mexico	Universidad Nacional Autonoma de Mexico	Postdoc	Foreign	Foreign	Foreign
Tropical Geometry	Nill	Benjamin	2005	Eberhard Karls Universitaet Tuebingen	Freie Universität Berlin	University of Gergia	Instructor	Foreign	Foreign	II
Tropical Geometry	Nisse	Mounir	2009	University Pierre et Marie-Curie	University Pierre et Marie-Curie	Texas A&M University	Assistant Profes	Foreign	Foreign	II
Tropical Geometry	Stapledon	Alan	2009	University of Michigan, Ann Arbor	University of Michigan, Ann Arbor	University of British Columbia	Postdoc	I Public	I Public	Foreign
Tropical Geometry	Williams	Lauren	2005	MIT	UC Berkeley	UC Berkeley	Assistant Profes	I Private	I Public	I Public



Tropical Geometry

Program Summary

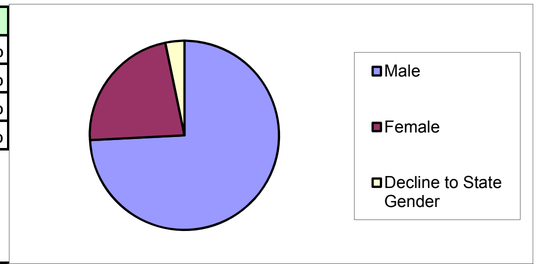
Role	# of Distinct Members	%	# of Citizens & Perm. Res.	%	# of Female	%	# of Minorities	%
Organizers	4	*6.5%*	2	*50.0%*	1	*25.0%*	0	*0.0%*
Research Professors	8	*12.9%*	1	*12.5%*	2	*25.0%*	0	*0.0%*
Postdoctoral Fellows	8	*12.9%*	3	*37.5%*	2	*25.0%*	0	*0.0%*
PD/RM	3	*4.8%*	2	*66.7%*	1	*33.3%*	0	*0.0%*
Research Members	29	*46.8%*	14	*48.3%*	6	*20.7%*	1	*7.1%*
Program Associates	10	*16.1%*	1	*10.0%*	2	*20.0%*	0	*0.0%*
Guests	0	*0.0%*	0	*0.0%*	0	*0.0%*	0	*0.0%*
Total no. of Distinct Members	**62**	***100.0%***	**23**	***37.1%***	**14**	***22.6%***	**1**	***4.3%***

Home Institute Grouping

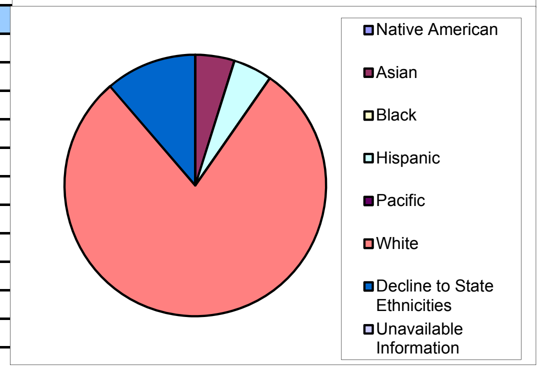
Role	Foreign	Group I Private	Group I Public	Group II	Group M	Non-Group	Total
Organizers	3		1				4
Research Professors	6		2				8
Postdoctoral Fellows	5		3				8
PD/RM		1	2				3
Research Members	18	1	3	3	2	2	29
Program Associates	9		1				10
Total	**41**	**2**	**12**	**3**	**2**	**2**	**62**
%	***66.1%***	***3.2%***	***19.4%***	***4.8%***	***3.2%***	***3.2%***	***100.0%***

Tropical Geometry Demographic Summary

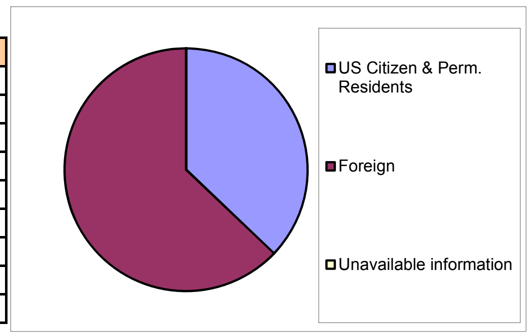
Gender	#	% (No Decl.)*	%
No. of Distinct Members	62		100.0%
Male	46	76.67%	74.2%
Female	14	23.33%	22.6%
Decline to State Gender	2		3.2%



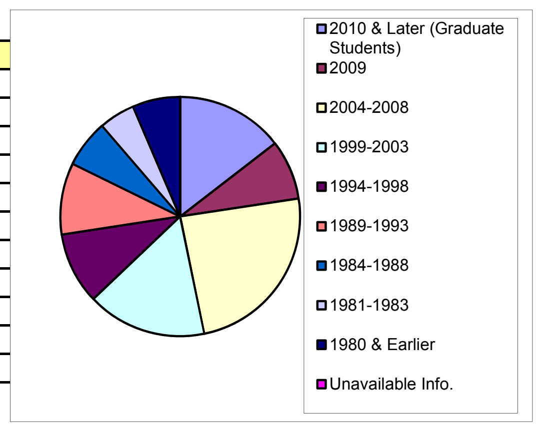
Ethnicities	#	% (No Decl.)*	%
Native American	0	0.00%	0.0%
Asian	3	5.45%	4.8%
Black	0	0.00%	0.0%
Hispanic	3	5.45%	4.8%
Pacific	0	0.00%	0.0%
White	49	89.09%	79.0%
Decline to State Ethnicities	7		11.3%
Unavailable Information	0		0.0%
No. of Distinct Members	62		100.0%
Minorities	1		4.3%



Citizenships	#		%
US Citizen & Perm. Residents	23		37.1%
Foreign	39		62.9%
Unavailable information	0		0.0%
No. of Distinct Members	62		100.0%
US Citizen	17		27.4%
Perm Residents	6		9.7%
Home Inst. in US	21		33.87%



Year of Ph.D	#		%
2010 & Later (Graduate Students)	9		14.5%
2009	5		8.1%
2004-2008	15		24.2%
1999-2003	10		16.1%
1994-1998	6		9.7%
1989-1993	6		9.7%
1984-1988	4		6.5%
1981-1983	3		4.8%
1980 & Earlier	4		6.5%
Unavailable Info.	0		0.0%
Total	62		100.0%



**Statistic Calculation based on all participants that did not decline.*

Program Report

Symplectic and Contact Geometry and Topology

Year-long program, 2009-10

Organizers:
Y. Eliashberg (Stanford), J. Etnyre (Georgia Tech), E. Ionel (Stanford), D. McDuff (Barnard), P. Seidel (MIT)

1 Introduction

MSRI has historically played a major role in our general area of mathematics. The first relevant program took place in 1988/89, just a few years after the invention of Symplectic and Contact Topology in their modern sense. In the twenty years since then, the field has grown enormously, and unforeseen connections with other areas of Mathematics and Physics have been found. By 2009, the time was ripe to reevaluate the achieved progress, and crystallize new ideas and promising direction of research.

The 2009/10 program in Symplectic and Contact Geometry and Topology, organized by Y. Eliashberg, J. Etnyre, E. Ionel, D. McDuff and P. Seidel, was designed to

- Promote the cross-pollination of ideas between different areas of symplectic and contact geometry;
- Help assess and formulate the main outstanding fundamental problems and directions in the field;
- Lead to new breakthroughs and solutions of some of these main problems;
- Discover new applications of symplectic and contact geometry in mathematics and physics;
- Educate a new generation of young mathematicians, giving them a broader view of the subject and the capability to employ techniques from different areas in their research.

The program ran in parallel with two tightly related semester-long programs: on Tropical Geometry in the Fall, and on Homology Theories for Knots and Links in the Spring. Both fields have close connections to ours, and the presence of experts in these areas was extremely beneficial. We also benefited from interactions with the UC Berkeley mathematics department on various levels, from graduate students to faculty members. The resulting productive research environment led to a number of high-profile results and breakthroughs, as well as starting developments in new directions.

2 Research Developments

Embedded Contact Homology and related invariants. One of major results obtained during the program is the proof of a long sought equivalence between Seiberg–Witten–Floer theory, Ozsváth–Szabó Heegaard homology theory and Hutchings–Taubes Embedded Contact homology (ECH) theory. Two groups of researchers successfully explored two different approaches to this problem, and this led to further developments within the program.

Taubes and Hutchings completed their work relating Seiberg–Witten–Floer theory to ECH. This has very important consequences, including a proof of the Arnold chord conjecture in 3 dimensions. In another fundamental step, Taubes found a way to establish the long sought equivalence between Seiberg–Witten–Floer theory and Ozsváth–Szabó theory, by building a direct geometric link between the ECH complex and the Ozsváth–Szabó complex. He is working out the details of this beautiful idea jointly with Yi-Jen Lee and postdoc Cagatay Kutluhan. A survey paper, and the first long installment of the proof, are now on the web.

At the same time, Colin, Ghiggini and Honda found a direct proof of the equivalence between Heegaard Floer homology and ECH. They use an entirely different approach, involving Giroux' open book decompositions contact 3-manifolods. This is still work in progress, but the first paper in a projected series has again been posted on the web.

Applications to embedding problems. The work of Taubes and Hutchings interacted productively with other developments in the program. Throughout the Spring semester, there was much discussion of the state of symplectic embedding problems in dimension 4. Several breakthroughs had been made just before, by Hind–Kerman and by McDuff–Schlenk. This prompted Hutchings to develop his ideas on ECH capacities sufficiently far for McDuff to prove the Hofer conjecture on embeddings of ellipses. Hind also introduced new ideas about embeddings of polydiscs, which turned out to be related to work of Fukaya–Oh–Ohta–Ono on displacing tori.

Symplectic Field Theory, Contact Homology and Applications. Bourgeois, Ekholm and Eliashberg developed a Legendrian surgery exact triangle for computing contact and symplectic homology, as well as some other symplectic invariants. In particular, this gave an explicit formula for the symplectic homology complex in terms of the Legendrian homology algebra of the attaching spheres. As an application, Postdoc Maydanskiy and UC Berkeley graduate student Ganatra showed that this implies the Seidel conjecture for symplectic homology of a manifold described as a Lefschetz fibration. As a consequence, concrete progress was made in constructing new exotic symplectic structures: for instance, Abouzaid and Seidel showed that any complex affine variety of sufficiently high dimension admits infinitely many convex at infinity distinct symplectic structures, not distinguished by classical homotopy theory. They, and independently postdoc McLean, also showed that $\mathbb{R}^{2n}$, $n \geq 6$, admits uncountably many distinct convex at inifinity symplectic structures (an analogue of the celebrated theorem of Gompf about differentiable structures on $\mathbb{R}^4$). Moreover, McLean showed that the problem of classifying Weinstein-type symplectic structures on T^*S^n, for $n \geq 7$, is algorithmically unsolvable. The corresponding question for $\mathbb{R}^{2n}$ is still open, but now looks ripe to be attacked. All this is fundamentally driven by advances in computing SFT invariants. Initiating the next step in these developments, very recent work of Bourgeois, Ekholm and Eliashberg finds a formula for the symplectic homology product, and some other invariants, in terms of the Legendrian homology algebra.

Several years ago Ng constructed combinatorial invariants of knots in $\mathbb{R}^3$ that have proven to be very effective invariants and surprisingly related to many very different classical knot invariants. Ekholm, Etnyre, Ng and Sullivan mostly completed work showing that Ng's invariant is really the contact homology of the conomral lift of a knot to the unit cotangent bundle of $\mathbb{R}^3$. More strikingly they showed how to lift a contact structure to the unit conormal bundle so that they could extend this invariant to an invariant of transverse knots in the standard contact structure on $\mathbb{R}^3$. Once again this is proving to be quite a powerful invariant that is able to distinguish many transverse knots that previous invariants could not (the only previous non-classical invariant is the recent Heegaard-Floer invariant of transverse knots). The algebraic structure behind this new invariant is quite reminiscent of the algebra behind all the various flavors of Heegaard-Floer homology. The exploration of these invariants and the algebraic structure of the invariants looks to be a fruitful line in inquiry. Ng has also managed to show how to construct this invariant in a purely combinatorial way.

Foundations. Equally important for the continued growth of field is work on analytic foundations, about which there were extensive discussions. The starting point was Wehrheim's lecture in the Introductory Workshop, which chastised the community for tolerating sloppy proofs. This sparked a workshop, whose aim was to introduce more researchers to the new Polyfold techniques of Hofer–Wysocki–Zehnder. Ultimately, the outcome of this workshop will appear as a "Polyfold for Dummies" guide. McDuff and Wehrheim also started a project to give a correct and detailed construction of the virtual moduli cycle for closed pseudo-holomorphic curves, using (if possible) the old, pre-polyfold techniques. This project was made possible by discussions that McDuff had with participants at MSRI (Fukaya, Taubes, Ruan, Mrowka, Fish, to name a few).

Fukaya categories, applications to non-displacement problems. Prior to the program, work of Fukaya-Oh-Ohta-Ono had led to significant advances in computing Fukaya categories of toric varieties. As a consequence of this and work of McDuff, we now know in many cases exactly which of the torus fibres are "essential" (can't be displaced by Hamiltonian symplectomorphisms). During this year, this has been extended some other types of Lagrangian tori, notably Chekanov-type tori in $S^2 \times S^2$, again by Fukaya-Oh-Ohta-Ono. Postdoc Ma'u continued her work with Wehrheim on Lagrangian correspondences, and showed that they induce functors between (suitably enhanced) Fukaya categories. Smith then applied this idea to Fukaya categories of intersections of quadrics. This work shows that, using the newly available methods, Fukaya categories for Fano varieties which are not toric can be computed efficiently, which marks an important milestone.

The classification and structure of Legendrian and transverse knots. Until recently the only transversely non-simple knot type for which Legendrian and transverse knots had been classified was the $(2,3)$–cable of the $(2,3)$–torus knot by Etnyre and Honda. During the program Etnyre, Ng and Vertesi classified Legendrian and transverse twist knots. Twist knots are a much study class of knots; for example, the 5_2 knot is the first knot to be shown to be non-Legendrian simple by Chekanov and independently Eliashberg. Among the twist knots is an infinite family of transversely non-simple knots.

In addition, Etnyre, LaFountain and Tosun classified Legendrian and transverse knots in the knot types obtained by any cable of the $(2,3)$-torus knot as well as many other torus knots. They also gave a procedure to studying any iterated torus knot. This gave another infinite family of transversely non-simple knot for which we have a classification result. Moreover, these classification results and the ones mentioned above exhibit many new interesting features not previous seen before.

Any attempt of pigeonholing developments into a few key areas, such as the one above, necessarily omits quite a bit of interesting research, which is of importance for the growth of the field. Nevertheless, some of it is represented in our accounts of the seminars and workshop below, and more in the description of the postdocs' work.

3 Organizational Structure

In addition to the workshops discussed below the organizers ran several structured events each week and encouraged members organize their own informal events tailored to their needs. The structured events were a research seminar, broken dreams seminar, working groups (these coved both mini-course like seminars and collaborative working seminars), a postdoctoral seminar and a graduate student seminar.

Research Seminar A weekly research seminar in Symplectic and Contact Geometry and Topology ran the entire year. This gave an opportunity for the more senior members to present their current research in an accessible way. We also heard some short term visitors (such as Brendan Guilfoyle, Petya Pushkar, David Gay) whose work was less familiar.

All the postdocs were invited to talk at this seminar at some time during the year.

Each lecture was scheduled for an hour and a half to give the speaker time to give some background information and time to answer questions.

Here is a list of people who presented:

Postdocs: Reza Rezazadegan, Mark McLean, Yasha Savelyev, Sonja Hohloch (twice), Brett Parker, Yank Lekili, Oliver Fabert, Lev Buhovski.

More senior members: Cliff Taubes, Janko Latschev, Octav Cornea, Tom Parker Richard Hind, Emmanuel Giroux, Michael Hutchings, Thomas Vogel, Ivan Smith, Josh Sabloff, Paolo Ghiggini, Brendan Guilfoyle, Petya Pushkar, David Gay, Greg Schneider.

Broken Dreams Seminar This was an informal seminar run during the Fall semester only. In these seminars the speaker discussed ideas that sound good but which did not quite work out. This was not a seminar where one talks about a theorem proved, but rather about results that might be true and which the speaker tried to prove, but did not succeed. Though there were only four talks in this seminar (by Cielieback, Taubes, Montgomery and Cornea) they were highly successful and popular. There was a great desire to keep them going in the Spring, but due to time constraints this did not happen.

Working Groups These were seminar series based around a certain theme. Some were in the form of learning seminars and some were aimed at fostering collaborative research projects.

FALL: There were four working groups.

1. Algebraic Structures of Holomorphic Curves. A particular goal of this working group was understanding the relation between two approaches for computing symplectic homology and other symplectic invariants of Liouville domains: one through Seidel-Abouzaid's approach through Fukaya category of vanishing cycles of a symplectic Lefschetz fibration, and the other one through Bourgeois-Ekholm-Eliashberg Legendrian surgery formalism. The group was organized by Sheel Ganatra, Maxim Maydanskiy and Yakov Eliashberg. The work of the group was also very helpful as a preparation for two workshops of the program devoted to algebraic structures in the theory of holomorphic curves.

2. Integrable Structures. The Integrable Structures workgroup was organized by Oliver Fabert, Paolo Rossi, and Dimitri Zvonkine who also gave almost all talks in the workgroup. There were covered four topics:

- Integrable systems via infinite-dimensional Grassmannians;

- Integrable systems via pseudo-differential operators;

- From Frobenius manifolds to integrable systems: the Dubrovin-Zhang construction;

- Open problems.

The goals were to systematize our knowledge of integrable systems and try to attack the open problems: explaining the appearence of integrable systems in SFT and in the intersection theory of the space of r-spin structures; understanding the integrable system that describes the Gromov-Witten invariants of a P^1-bundle.

3. Polyfolds. The group was organized by Joel Fish, Oliver Fabert and Roman Golovko to study the new foundational theory of polyfolds which is currently being developed by Hofer, Wysocki and Zehnder. Given the size, scope, and quite technical nature of polyfolds and their applications, the main goal of the working group was not to provide a complete treatment of the subject, but rather to provide an overview which was accessible to a diverse audience of symplectic and contact geometers. In particular, a distinct effort was made to present material in an approachable manner to both specialists and non-specialists alike. The organizers took turns presenting the material after frequent meetings amongst themselves to resolve difficulties and enhance clarification. The term began with a discussion of the strengths and weaknesses of alternate approaches to transversality problems. Next, the main definitions of the polyfold theory were presented (e.g. sc-Banach spaces, the sc-calculus, sc-retractions, M-polyfolds, strong bundles etc); illustrative examples were provided in parallel. With the basics established, the working group moved on to the statements of the main theorems, namely the abstract perturbation result which resolves transversality issues. Finally, the term culminated with a discussion of polyfolds in a broader context, with an emphasis on how the abstract analytic framework of polyfolds drastically reduces the amount of future work needed to build smooth compact moduli spaces in a wide variety of settings. One of the goal was to create a "User Guide to Polyfolds" which wold provide an entrance point to this large subject for mathematicians interested in applications of the theory. Jointly with Katrin Wehrheim Fabert, Fish and Golovko are working on producing the text.

4. Giroux Correspondence in higher dimensions. In this seminar organized by Vera Vertesi participants tried to construct a complete proof of the Grioux correspondence between open book decompositions and contact structures in high dimensions. While this was not ultimately achieved a thorough outline of the program was understood along with many details and issues that come up along the way. Speakers at this group included Lev Buhovski, Yang Huang, Selman Akbulut, and Sonja Hohloch – people with very varied backgrounds.

SPRING: There were two working groups but there was an informal working group and much participation in a working group for the other program on Boarded Heegaard Floer Homology.

1. Quantitative Symplectic Topology. This was run by Leonid Polterovich and Dusa McDuff. The idea was to present some open problems and present recent relevant work. Some of the developments which occurred in this context have already been described above. Michael Hutchings' talk about *Symplectic embedding obstructions from ECH (Embedded Contact Homology)* was a significant contribution to the aims of the workshop. Kenji Fukaya spoke about *Cyclic symmetry enumerative invariants and mirror symmetry*, which was of interest because of applications to Lagrangian (non)displacement, especially in comparison with Polterovich's work on quasi-states. As a side-note, we point out that the focus on developing quantitative measures was also reflected elsewhere in the program. For example, Mark McLean's research seminar lecture on *The growth rate of symplectic homology and applications* was absolutely in the spirit of this working group.

2. Symplectic Geometry and Representation Theory. The initial idea of this seminar was to use mirror symmetry for hyperkaehler manifolds, as a way to link symplectic geometry to representation theory on a categorical level. The seminar had several ultra-short talks each meeting followed by more lengthy discussions. Participants included Paul Seidel, Ivan Smith, Mohammed Abouzaid, Sabin Cautis, and Catharina Stroppel (the last two were members of the concurrent HTKL program). In particular, the group explored the symplectic meaning of several representation theory constructions introduced by Stroppel. Intended future applications are to symplectic Khovanov homology.

3. Sutured Manifolds and the Contact Category. This was an informal seminar that gave an introduction to the contact invariant in Sutured Heegaard Floer Homology followed by an series of talks by Honda on the Contact Category. This was the first extended exposition on this theory that is still in development.

Postdoctoral Seminar This was a joint seminar between the Symplectic and Contact Geometry and Topology program an the Tropical Geometry program in the Fall and the Homology Theories of Knots and Links program in the Spring. Each week one postdoctoral fellow from each program gave a 30-45 minute talk on their research. In the Spring non-post docs and graduate students were banned from these talks to provide a more laid-back environment in which communication between the programs could more easily flourish.

Graduate Student/Learning Seminar This was a joint seminar between the programs (between symplectic geometry and tropical geometry programs in the Fall semester, and between symplectic geometry and homology theories program in the Spring semester). In the Fall it was organized by Jian He, and in the Spring by Megumi Harada and Tara Holm. The style of work of the seminar was different in 2 semesters. In the Fall with a few exceptions gave talks by themselves, while in the Spring the seminar series was thematic, recruiting visiting (and local) experts to speak on a number of topics which the participating students were interested in learning. Speakers were asked to prepare 45-minute talks, but the sessions often lasted the full 90 minutes because of the active question-and-answer/discussions which took place during and after the talks. To give an example, Reza Rezazadegan gave a memorable talk in which he spent only 5 minutes introducing the "bare bones" of symplectic Khovanov homology, and then turned to the audience and asked, "Are there any questions?" The audience laughed, and then started peppering Reza with requests for more detailed definitions/explanations of the terms he had placed on the board. The rest of the talk – which lasted fully 90 minutes! – proceeded in much the same (conversational and interactive) manner. Attendance was regularly high, due in part to the effort made by the speakers to give accessible and introductory talks. To give a sense of the level of attendance, we note that there were 16 people who signed up for the "SCGT student learning seminar" e-mail list; however, many of the seminars were attended by lots of other MSRI research visitors not on the e-mail list. For instance, Michael Hutchings' introductory talk on embedded contact homology was so well-attended that the Baker Boardroom was jam-packed (all seats were taken). Denis Auroux's talk on Lefschetz fibrations was overfull and had to be moved to the Simons auditorium.

4 Workshops and Conferences

1. Summer Graduate Workshop: Symplectic and Contact Geometry and Topology August 3, 2009 to August 14, 2009 Organized By: John Etnyre (Georgia Tech), Dusa McDuff (Barnard) and Lisa Traynor (Bryn Mawr). The goal of this workshop was to introduce a diverse group of students to most of the basic tools used in symplectic and contact geometry and topology, as well as to introduce some of the driving questions that motivate the field today. There were 6 lecture series: An introductory lecture series by Margaret Symington (Mercer), a series on capacities and symplectic packing by Dusa McDuff (Barnard), an introductory lecture series by John Etnyre (Georgia Tech), a series of lectures on contact homology by Lenny Ng (Duke), an introductory lecture series by Katrin Wehrheim (MIT) and a series on Floer homology by Ely Kerman (UIUC). There were many other activities including problem sessions, a few research talks and a capstone meeting to give a summary of what was covered, what we were not able to cover and point towards future research.

Both organizers thought the somewhat unusual circumstance of this graduate program (i.e. that it was followed immediately by a workshop for a main program in the same area) worked out very well. Several of the graduate students were able to extend their learning experience by staying for the Introductory Workshop. The direct and indirect feedback the organizers heard from both students and lecturers was uniformly positive, and points to the workshop having been highly successful.

2. Connections for Women: Symplectic and Contact Geometry and Topology August 14, 2009 to August 15, 2009 Organized By: Eleny Ionel (Stanford), Dusa McDuff (Barnard). The main goal of this workshop was to provide a way for women interested in symplectic and contact geometry to meet and get to know each other, partly by hearing talks by one another and partly in more social settings. Many junior women are starting careers in this field and we wanted to provide an opportunity for everyone to hear about their work. The first morning of the meeting also coincided with the end of a Graduate Student workshop on this topic, and so we started with two survey lectures that were intended both to sum up the work of the previous two weeks for the graduate students and provide an interesting survey of the area for the newcomers. We had four one-hour talks by midcareer/senior women illustrating the breadth of the field, six half hour talks by junior women on a wide variety of topics, with time scheduled in for discussions, and a collection of posters by graduate students and postdocs (organized by Margaret Symington). There was also a panel discussion led by Tara Holm with participation by Katrin Wehrheim, Lisa Traynor, Susan Tolman, Gordana Matic, and Margaret Symington. The panelists first talked briefly about their career paths and different choices about family issues, then they answered questions from the audience. The highlight of the social events was dinner at a Nepali restaurant.

We tried to create a friendly atmosphere in the lecture hall to encourage discussion and questions. For example, the lecturers all gave brief descriptions of their careers to date, so that the audience would know a little about them. Senior members of the audience asked questions and made comments to encourage the others. This seemed to work well. Also the attempt to facilitate communication between the equivariant group and the symplectic topologists seemed to work. One participant mentioned later in the program how useful the Connections had been. She said that at a large conference one tends to talk to people one knows, and this gave her a chance to get to know several people. Another participant mentioned how illuminating the panel discussion had been; she realized that problems/concerns she had thought hers alone were shared by many others. A third one (who had earlier expressed some scepticism about events just for women) said that she had met someone at the dinner whom she would not otherwise have talked to and that was valuable.

3. Introductory Workshop: Symplectic and Contact Geometry and Topology August 17, 2009 to August 21, 2009 Organized By: John Etnyre (Georgia Tech), Dusa McDuff (Barnard), and Lisa Traynor (Bryn Mawr). The main goals of the workshop were to introduce people working in some sub-discipline of the field or in a completely different area to a broad swath of the field and frame the most important problems and subareas to give some shape to the year long program. While not able to cover this immense field completely we focused on four broad areas that will be the basis for most of the activities during the coming year. Specifically we focused on (1) *Symplectic field theory*, (2) *Floer homology*, (3) *Topological aspects*, and (4) *Applications*. For each topic we had a blend of mini-courses introducing the main ideas of the area and a few other talks aimed more at exposing the lay of the land and future directions for the field, than at one specific research result. In addition we had two very introductory lectures introducing the history and basic ideas in symplectic and contact geometry and topology. Generous breaks between the lectures was also an integral part of the workshop as it allowed the participants time to interact with the speakers and amongst themselves.

Several people commented to the organizers that some of the talks in areas they knew less well helped clarify a new aspect of the field for them. We also heard comments from some of the graduate students who had attended the earlier Graduate Workshop that they had understood most of the talks in the Introductory workshop and felt they had a good overview of the field. Repeated comments of this sort, and the attendance of many of the talks by MSRI members not associated with the symplectic and contact program, allow us to conclude that the workshop certainly met its first stated goal above. There is also every indication that the second goal was achieved as well, given that the organizers carefully consulted with the organizing committee for the year long program.

4. Algebraic Structures in the Theory of Holomorphic Curves November 16, 2009 to November 20, 2009 Organized By: Mohammed Abouzaid (Clay), Yakov Eliashberg (Stanford), Kenji Fukaya (Kyoto), Eleny Ionel (Stanford), Lenny Ng (Duke), Paul Seidel (MIT).

This workshop was run in conjunction with another one at AIM (Palo Alto) the week before. The idea, which proved very successful, was to first assemble key specialists for informal discussion (at AIM), and then to put the issues and results of that discussion in a wider perspective (at MSRI). This wider context included: Symplectic Field Theory (talks of Ekholm, Cieliebak, Bourgeois, and others); integrable systems theory (Rossi, Dubrovin, Givental, Liu); mirror symmetry (Fukaya, Smith); the formalism of general Cohomological Field Theories (Teleman, Woodward, Galatius). Bringing together these multiple viewpoints has stimulated further progress since then, for instance Fabert's collaboration with Rossi on integrable system aspects of Symplectic Field Theory.

5. Symplectic and Contact Topology and Dynamics: Puzzles and Horizons March 22, 2010 to March 26, 2010 Organized By: Paul Biran (Tel Aviv), John Etnyre (Georgia Tech), Helmut Hofer (Courant), Dusa McDuff (Barnard), Leonid Polterovich (Tel Aviv).

The workshop focused on recent progress on central problems in symplectic and contact topology and Hamiltonian dynamics, such as: rigidity of Lagrangian submanifolds; algebra/topology/geometry of symplectomorphism and contactomorphism groups; exotic symplectic and contact structures; and existence of periodic orbits of Hamiltonian systems and Reeb flows. It explained applications of the "large machines" such as Floer Theory, Symplectic Field Theory and Fukaya categories, as well as showing where these machines do not yet provide satisfactory answers. Special attention was paid to articulating new problems and directions, as well as to explaining interactions between symplectic and contact topology and other fields. In order to hear new points of view the organizers invited many speakers who otherwise were not involved in the program.

Highlights include Taubes' talk on his work with Hutchings, solving the chord conjecture in dimension three (both Taubes and Hutchings were program members while this work was being done). Another notable breakthrough was completed during the workshop itself, since that allowed all collaborators to meet: the proof that $\widehat{ECT} = \widehat{HF}$, announced by Honda on the penultimate day. Many participants emphasized having highly productive discussions during the workshop, which advanced their own research.

6. Symplectic Geometry, Noncommutative Geometry and Physics May 10, 2010 to May 14, 2010 Organized By: Robbert Dijkgraaf (Amsterdam), Tohru Eguchi (Kyoto), Yakov Eliashberg (Stanford), Kenji Fukaya (Kyoto), Yoshiaki Maeda (Yokohama), Dusa McDuff (Barnard), Paul Seidel (MIT), Alan Weinstein (Berkeley).

The workshop was jointly organized and jointly funded with the Hayashibara Forum (Japan). The focus of the workshop was the interactions between symplectic geometry, non-commutative geometry and Physics. The program consisted of minicourses and lectures given by mathematicians and physicists. Minicourses were given by Katrin Wehrheim, Yan Soibelman and Denis Auroux. Among physics lecturers were Mina Aganagic, Tohru Eguchi, Anton Kapustin and Hiroshi Oguri.

5 Postdoctoral Fellows

Lev Buhovsky

PhD: Tel Aviv University, 2009
Position prior to MSRI membership: none
Position after MSRI membership: postdoc at the University of Chicago
Mentor: Octav Cornea, Yasha Eliashberg, Leonid Polterovich

Activities: Lev worked with the UC Berkeley graduate student Sobhan Seyfaddini on the C^0 symplectic topology, leading to the preprint "Uniqueness of generating Hamiltonians for continuous Hamiltonian flows". He also worked with Michael Entov and Leonid Polterovich on the rigidity of the Poisson bracket, and they are currently writing a joint paper on the subject. Lev also worked with Yaron Ostrover on the subject of bi-invariant Finsler metrics on the group of Hamiltonian diffeomorphisms. Their preprint "On the Uniqueness of Hofer's Geometry" is available on arxiv.org.

Andrew Cotton-Clay

PhD: UC Berkeley, 2009
Position prior to MSRI membership: none
Position after MSRI membership: Benjamin Peirce Lecturer and NSF Postdoctoral Fellow, Harvard University
Mentor: Denis Auroux

Andrew's research focused on applications of holomorphic curves to symplectic and contact geometry, and to geometry and topology, in low dimensions. There are only limited cases in which we have a thorough understanding of rigid holomorphic curves in symplectizations of contact or stable Hamiltonian manifolds. In the case of mapping tori over T^2, and for many cases for mapping tori over higher genus surfaces, he obtains a complete description of rigid holomorphic pairs of pants. This has applications to periodic Floer homology, and to the symplectic field theory of the natural stable Hamiltonian structure on the mapping tori. It also has connections to number theory, and one may expect applications to contact 3-manifolds via open books.

Preprints: Holomorphic pairs of pants in mapping tori, preprint

Oliver Fabert

PhD: University of Munich (LMU) 2008
Position prior to MSRI membership: University of Munich (LMU)
Position after MSRI membership: postdoc at Max Planck Institute, Leipzig, Germany
Mentor: Eleny Ionel

Oliver Fabert received his Ph.D. from the University of Munich (LMU) in 2008 under the supervision of Kai Cieliebak. His dissertation was entitled "Transversality results and computations in symplectic field theory" and was in parts written up during his one semester stay at the Swiss Federal Institute of Technology (ETH) in Zurich, Switzerland while joining Dietmar Salamons working group. While at MSRI Oliver continued thinking about the transversality problem for holomorphic curves, mostly together with his mentor Eleny Ionel, as well as the integrable systems structure that naturally appears in symplectic field theory, where he continued his joint work with Paolo Rossi. As results of this intensive joint work during his stay at MSRI they so far wrote two joint papers on "String, dilaton and divisor equation in symplectic field theory" (ArXiv preprint 1001.3094) and "Topological recursion relations in non-equivariant cylindrical contact homology" (ArXiv preprint 1007.2287). In both papers the stay at MSRI is greatly mentioned. Together with Joel Fish and Roman Golovko he organized a working group on Hofer-Wysocki-Zehnders polyfold theory which claims to solve the above transversality problem in full generality, see also the survey "Transversality problems in symplectic field theory and a new Fredholm theory" on the Arxiv (1003.0651). Furthermore he organized with Paolo Rossi and Dimitri Zvonkine a second (of four) working group exploring the relation between holomorphic curves and integrable systems. Apart from the people he already mentioned, he benefitted very much from discussions with many other great researchers like Yasha Eliashberg, Octav Cornea and Clifford Taubes.

Agnes Gadbled

PhD: Université Louis Pasteur de Strasbourg, 2008
Position prior to MSRI membership: post-doc at Institut de Mathematiques de l'Université de Neuchatel
Position after MSRI membership: resumes previous position
Mentor: Kai Cieliebak, Richard Hind

Gadbled described families of monotone symplectic manifolds constructed via the symplectic cutting procedure of Lerman from the cotangent bundle of manifolds endowed with a free circle action. She also gave an obstructions to the monotone Lagrangian embedding of some compact manifolds in these symplectic manifolds. These results appeared in the paper "Families of monotone symplectic manifolds constructed via symplectic cut and their Lagrangian submanifolds".

Roman Golovko

PhD: USC, 2009
Position prior to MSRI membership: none
Position after MSRI membership: CIRGET postdoctoral fellow at the Universite de Montreal and Universite du Quebec a Montreal.

Mentor: Mike Hutchings

While at MSRI, Golovko have prepared the following preprints:

"The embedded contact homology of sutured solid tori", arXiv:0911.0055, submitted;

"The cylindrical contact homology of sutured solid tori", arXiv:1006.4073.

In addition, at MSRI he started a collaboration with Oliver Fabert, Joel Fish, and Katrin Wehrheim working on applications of the theory of polyfolds.

Jian He

PhD: Stanford University, 2006
Position prior to MSRI membership: postdoc at USC
Position after MSRI membership: postdoc at Université Libre, Brussels
Mentor: Kai Cieliebak, Mike Hutchings

Jian spent at MSRI the Fall semester. He worked on completing his paper on contact homology of subcritical Stein manifolds. Overcoming several unexpected technical difficulties Jian completed a first draft of the paper. Besides working with his mentors Cieliebak and Hutchings, Jian also regularly interacted with Eliashberg. He also benefited a lot from discussions with F. Bourgeois who visited MSRI for the November workshop.

Jian also actively participated in the work of the working group on polyfolds and supervised the work of the graduate student seminar. Beginning September 2010 Jian accepted a postdoctoral position at Université Libre in Brussels where he will continue his work under the direction of Bourgeois.

Sonja Hohloch

PhD: University of Leipzig, 2008
Position prior to MSRI membership: postdoc at Tel Aviv University, Minerva Fellowship
Position after MSRI membership: postdoctoral at Stanford University, fellowship from the

German Research Foundation
Mentor: Eleny Ionel, Cliff Taubes

Together with G. Noetzel (Leipzig), Sonja started working on a project about n-categories and higher Morse moduli spaces. Moreover, they interpreted their joint work with D. Salamon about hyperkaehler Floer homology in terms of infinite dimensional Hamiltonian systems on the double iterated loop space. Sonja also spent a lot of time discussing certain aspects of symplectic dynamical systems with many of the senior mathematicians at the MSRI while she was revising a submitted preprint about homoclinic points and Floer homology. She also spent some time thinking about the relation between certain cube diagrams and hyperkaehler Floer homology with Scott Baldridge (LSU), who visited MSRI in January. Sonja also gave talks: one in the 'Connections for Women workshop', and two talks each in the Symplectic Research Seminar, the Postdoc Seminar and the working group on 'Giroux correspondences'.

Preprints: 1) Homoclinic points and Floer homology (submitted; revising) 2) n-categories and higher Morse moduli spaces (with G. Noetzel) 3) Hyperkaehler Floer theory as infinite dimensional Hamiltonian system on the iterated loop space and the Maslov index (with G. Noetzel)

Sonja mentioned: " I very much liked the Symplectic Year at the MSRI since it provided ample opportunity to discuss problems directly with the experts. Moreover, I got to know many people working in symplectic geometry — I feel much more comfortable to write an email about a mathematical question to a person I know than to somebody whom I only know from the literature..."

Cagatay Kutluhan

PhD: University of Michigan, 2009
Position prior to MSRI membership: none
Position after MSRI membership: Ritt Assistant Professor at Columbia University
Mentor: Ko Honda, Cliff Taubes

Cagatay Kutluhan received his Ph.D. from the University of Michigan, Ann Arbor in 2009 under the supervision of Daniel M. Burns, Jr. His dissertation was titled "Floer homology and symplectic forms on $S^1 \times M^3$." While at MSRI Cagatay continued thinking about generalizations of his thesis result as well as related other problems. He also investigated several constructive methods in contact and symplectic topology and their interplay with gauge theory and Floer homology. He learned a great deal more about the latter through seminars, working groups and by direct contact with experts in the field. Moreover, he started a project with Tolga Etgu and Bulent Tosun during his stay. However, the most exciting progress in his research took place in the beginning of 2010 when he and his collaborators Yi-Jen Lee and Clifford Henry Taubes finally figured out how to prove the equivalence of Heegaard Floer homology and Seiberg-Witten Floer homology. They have already posted two of the five preprints that prove this equivalence on arXiv in Summer of 2010. After his stay at MSRI, Cagatay started his position as a Ritt Assistant Professor at Columbia University.

Preprints: HF=HM I : Heegaard Floer homology and Seiberg–Witten Floer homology with Yi-Jen Lee and Clifford H. Taubes available at arXiv:1007.1979
HF=HM II : Reeb orbits and holomorphic curves for the ech/Heegaard Floer correspondence with Yi-Jen Lee and Clifford H. Taubes available at arXiv:1008.1595

Yanki Lekili

PhD: MIT, 2009
Position prior to MSRI membership: none
Position after MSRI membership: junior research fellow at Cambridge University
Mentor: Ko Honda

Yanki received his PhD from MIT in May 2009 under the supervision of Denis Auroux, so the postdoc position at MSRI was his first experience as a researcher after graduate school. Overall, he mentioned that had an outstanding research/learning experience at MSRI. While at MSRI, Yanki worked on several projects, some of which were initiated and completed at MSRI. As for the latter, he completed two joint papers on open books and contact structures, one of these with Tolga Etgü and the other with Burak Ozbagci. Both of these papers are published now (IMRN & MRL). Yanki also completed another preprint with Max Lipyanskiy on quilted Floer homology. Finally, he made significant progress on his joint paper with Tim Perutz, concerning an extension of Heegaard Floer invariants to three-manifolds with boundary. This latter work is still in progress. As for the learning experience, he feels that he has learned quite a bit from numerous seminar talks and conferences that he attended while at MSRI. In particular, the seminars organized by Yakov Eliashberg and Paul Seidel were really interesting and made him realize new research directions that he is planning to pursue in the future. After his stay at MSRI, Yanki took a position at the Max-Planck Institut in Bonn for the summer followed by a junior research fellow position at the University of Cambridge for the upcoming years.

Maksim Maydanskiy

PhD: MIT, 2009
Position prior to MSRI membership: none
Position after MSRI membership: postdoc at Cambridge University followed by NSf postdoc at Stanford University
Mentor: Yasha Eliashberg, John Etnyre, Paul Seidel

While at MSRI, Maksim worked on two papers on exotic symplectic structures on cotangent bundles of spheres and and related spaces. One, joint with Paul Seidel, has now appeared in Topology (M. Maydanskiy and P. Seidel. Lefschetz fibrations and exotic symplectic structures on cotangent bundles of spheres. J. Topology, 3:157 V180, 2010.). The other is being revised for Geometry and Topology (available as http://arxiv.org/abs/0906.2224v1). These are based on Maksim's thesis computations in wrapped Fukaya category. At MSRI he continued thinking about the wrapped Fukaya category, and its relation to the symplectic homology and other symplectic invariants (contact homology, SFT...). One of the results of this was an appendix to Effect of Legendrian Surgery by Frederic Bourgeois, Tobias Ekholm, Yakov Eliashberg (arXiv:0911.0026v3), that he wrote with Sheel Ganatra on relating the BEE surgery method for working with symplectic homology of Weinstein manifolds to the Seidel picture for Lefschetz fibrations.

Mark McLean

PhD: Cambridge University, 2008
Position prior to MSRI membership: postdoc at MIT
Position after MSRI membership: resumes previous position
Mentor: Lenny Ng, Viktor Ginzburg

Mark spend his time at MSRI working on two papers on symplectic homology. The first paper "A Spectral sequence for symplectic homology" constructs a spectral sequence converging to symplectic homology of a Lefschetz fibration whose E^1 pages are Floer homology groups of the monodromy symplectomorphism of this Lefschetz fibration; this is then used to prove a theorem about fixed points of certain symplectomorphisms. The second paper, " The growth rate of symplectic homology and applications" prove several properties of an invariant of Liouville d omains called the growth rate of symplectic homology. Mark uses growth rates to show that the unit cotangent bundle of a rationally hyperbolic manifold is not Stein fillable by a smooth affine variety. Mark also has a growth rate criterion for infinitely many Reeb orbits, and a sketch of a computability result which will be written up in a third paper.

Sikimeti Ma'u

PhD: Rutgers University, 2008
Position prior to MSRI membership: postdoc at MIT
Position after MSRI membership: NSF postdoc at Barnard College
Mentor: Denis Auroux, Eleny Ionel, Dusa McDuff

While at MSRI Sikimeti worked on analytical and algebraic aspects of Quilted Floer theory. During the Fall 2009 she completed "Gluing Pseudoholomorphic Quilted Disks", and in the spring 2010 she started "Quilted strips, graph associahedra, and A-infinity n-modules" (completed) and "A-infinity bimodules for Lagrangian correspondences" (near completion).

Sikimeti mentioned that: " Probably the biggest benefit was the networking aspect, getting to know people who work in the field, being able to talk to them in person. Another benefit was finding out the interesting directions people are moving towards now, and getting lots of new ideas for one's own research."

Brett Parker (joint with the Tropical Geometry program)

PhD: Stanford, 2005
Position prior to MSRI membership: UC Berkeley, visiting postdoc
Position after MSRI membership: postdoc at University of Zurich
Mentor: Yasha Eliashberg, Mark Gross, Michael Sullivan

Brett Parker received his Ph.D. from Stanford in 2005 under the supervision of Yakov Eliashberg. His dissertation was titled 'Holomorphic curves in Lagrangian torus fibrations'. In his time at MSRI, Brett Parker worked on generalizing the symplectic sum formula for Gromov Witten theory using the holomorphic curve theory of a new category called the category of exploded manifolds. In this formalism, a symplectic manifold which is the result of a generalized symplectic sum is is connected in a smooth family of exploded manifolds to an exploded manifold in which the computation of Gromov Witten invariants reduces to a sum of relative invariants over tropical curves. In the familiar case of a symplectic sum, the relative invariants are Gromov Witten invariants relative to a symplectic submanifold, and the tropical curves are in an interval and do not play an important role in understanding the symplectic sum formula. In other cases however, the tropical curves are in a polytope of dimension as high as half the dimension of the symplectic manifold, and sometimes the computation of Gromov Witten invariants reduces to a combinatorial problem of a count of tropical curves. The relative invariants involved can be regarded as a version of Gromov Witten invariants relative to normal crossing divisors. At MSRI, Brett Parker was able to confirm a functorial connection between his work in exploded manifolds and the work of Mark Gross and Bernd Siebert on mirror symmetry using log geometry and tropical geometry. While at MSRI, Brett Parker worked on five papers, the first 3 of which he posted on the arXiv: 'Exploded Manifolds' - an introductory paper which established basic differential geometry properties of exploded manifolds, 'Holomorphic curves in Exploded manifolds: compactness' - a paper which established the compactness results necessary for Gromov Witten invariants, 'DeRham theory of Exploded Manifolds', a paper which proved various results needed for defining Gromov Witten invariants of exploded manifolds using integration of differential forms, 'Holomorphic curves in Exploded manifolds: regularity' - a paper which establishes the regularity results for families of holomorphic curves necessary for defining Gromov Witten invariants, and 'Gromov WItten invariants of exploded manifolds', in which Gromov Witten invariants of exploded manifolds are defined.

Brett's postdoc at MSRI allowed him to explain his approach to tropical geometry to many members of the Tropical Geometry program and to understand connections to Mark Gross and Berndt Siebert's approach to tropical geometry and mirror symmetry using Log geometry. He also understood the connection between the exploded semialgebra, which he works with, and Oleg Viro's multiple valued fields operations. Brett's participation in the symplectic and contact geometry and topology program allowed him to explain to symplectic topologists how exploded manifolds are useful in symplectic topology, and to benefit from the collective expertise of the other members of that program that work with holomorphic curves. After his stay at MSRI, Brett took up a postdoctoral research position at the University of Zrich.

Paolo Rossi

PhD: SISSA - Trieste, 2008 Position prior to MSRI membership: Postdoc at Ecole Polytechnique, Paris
Position after MSRI membership: postdoc at Institut de Mathematiques de Jussieu, Paris VI
Mentor: Yasha Eliashberg, Alexander Givental

During his stay at MSRI Paolo benefited from the active scientific environment and from discussions with many experts, among them his mentors Yakov Eliashberg and Alexander Givental. He also started a very fruitful collaboration with Oliver Fabert about gravitational descendants in SFT which is still giving results. They wrote a joint paper "String, dilaton and divisor equation in Symplectic Field Theory" at MSRI which was submitted to IMRN and is now at an advanced state of the correction and publication process. From there they went on the same project and they are already producing the third paper of the series.

Yasha Savelyev

PhD: SUNY Stony Brook, 2008
Position prior to MSRI membership: postdoc at U Mass Amherst
Position after MSRI membership: resumes previous position
Mentor: Leonid Polterovich and Dusa McDuff

While at MSRI, Yasha worked on the paper *On Gromov K-Area*, and revised *Bott periodicity and stable quantum classes*, both now on the arxiv. He gave a well received talk in the research seminar, and also talked to many people about new ideas, including Hutchings, Teleman, Givental, Eliashberg, Bukhovsky as well as Polterovich and McDuff.

Van Horn-Morris, Jeremy

PhD: University of Texas, 2007
Position prior to MSRI membership: postdoc at Universite du Quebec a Montreal (CIRGET)
Position after MSRI membership: postdoc at American Institute of Mathematics (also held during MSRI year)
Mentor: John Etnyre

During his stay at MSRI, Jeremy worked with John Etnyre and finished "Cabling, contact structures and mapping class monoids, " accepted to IMRN. He also worked with Tom Mark and finished "Monodromy Substitutions and Rational Blowdowns." Finally, Jeremy worked with Sam Lisi and Chris Wendl on "Symplectic Fillings of Plumbed open books," still in progress.

Jeremy mentioned about his stay at MSRI: "I started many other projects informally, often with people in the Knot Homologies group resulting in too many ideas but few results. It was a very productive and energizing time."

David Shea Vela-Vick (joint with Homology Theories of Knots and Links Program)

PhD: University of Pennsylvania, 2009
Position prior to MSRI membership: none
Position after MSRI membership: NSF Postdoc Fellowship (also held during the MSRI year)
Mentor: John Etnyre

While at MSRI, David revised his joint paper with John Etnyre titled "Torsion and Open Book Decompositions". In joint work with John Etnyre they defined an invariant of knot and Legendrian knots using limits of sutured Heeegaard-Floer invariants. David also made progress in showing that this invariant is related to HFK^{-}. He completed the paper "Legendrian contact homology and nondestabilizability" with Clayton Shonkwiler.

Vera Vertesi (joint with Homology Theories of Knots and Links Program)

PhD: Eötvös Loránd University, 2009
Position prior to MSRI membership: none
Position after MSRI memership: postdoc at MIT
Mentor: John Etnyre

During her stay at MSRI, Vera finished a paper about the classification of Legendrian representations of twist knots with J. Etnyre and L. Ng. She was also working on a Reidemeister-type theorem for contact structures on a surface cross interval obtained by a sequence of bypass attachments.Vera now has several ongoing projects. With J. Baldwin and J. Etnyre they are defining an invariant in sutured Floer homology for arcs, and an element in it for Legendrian arcs. With J. Etnyre and L. Ng they can classify transverse representations of some cables of some Legendrian simple types. Vera also started to study the use of bordered Floer homology in understanding the rank of Heegaard Floer homology.

6 Graduate Students

Student	Advisor (and program member)
Luis Diogo	Yasha Eliashberg
Viktor Fromm	Wilhelm Klingenberg
Sheel Ganatra	Denis Auroux
Andreas Gerstenberger	Kai Cieliebak
Penka Georgieva	Eleny Ionel
Ilya Grigoriev	Yasha Eliashberg
Josua Groeger	Klaus Mohnke
Jen Hom	Paul Melvin
Yuan Huang	Ko Honda
Max Murphy	Yasha Eliashberg
Bulent Tosun	John Etnyre
Chung-Jun Tsai	Cliff Taubes

In addition, a large group of graduate students from UC Berkeley participated regularly in our activities (to enable this, the organizers made an effort to keep the schedules compatible with those of classes at the University).

The MSRI program was a very valuable experience for the graduate students who participated. Many of them made significant strides in their own research. For example, Jen Hom completed the paper "A note on cabling and L-space surgeries" as well as work on a preliminary draft of another paper that completely determines the much studied behavior of the τ-invariant under cabling. Other examples include Yuan Huang completion of his work on a convex surface theory proof of Eliashberg's well known theorem that overtwisted contact structures are determined by their homotopy class of plane field and Bulent Tosun's completion of work with LaFauntain and Etnyre concerning the Legendrian and transversal classification of iterated torus knots. Sheel Ganatra was a co-organizer of a working group on "Algebraic structures in the theory of holomorphic curves" and gave a series of lectures there. In addition to the specific research accomplishments several graduate students felt this was an invaluable program that allowed them to get a much broader perspective on symplectic and contact geometry.

7 Diversity

Our diversity efforts were mostly focussed on encouraging participation by women. Symplectic geometry is often considered a field where there are lots of women, but in fact rather few of the more senior women work in symplectic and contact topology, which is the part of the subject emphasized by the program. However, there is quite a large group in the related area of equivariant symplectic geometry, for example Yael Karshon, Susan Tolman, Tara Holm, Rebecca Goldin and younger women such as Megumi Harada and River Chang. Many of this group did manage to come for extended periods of time and get involved in the program. For example, Holm and Harada were enthusiastic organizers of the graduate learning seminar.

There are a good number of women who are centrally in the field, such as Katrin Wehrheim, Yi-Jen Li, Gordana Matic, Basak Gurel, Olga Buse, and Melissa Liu; they also played very visible roles. We also invited many young women researchers from the US and abroad; for example Gadbled, Mandini, Ma'u, Hohloch, Sandon, Chang. There were certainly enough women at MSRI to create a vibrant atmosphere in which one's gender was not an issue.

We also tried to encourage participation by other underrepresented groups. For example, several African American mathematicians participated at various workshops during the program.

8 Synergistic activities

One of the keys to the success of our program was the interaction with the parallel programs. It is clear from the above description that we had significant interactions between the programs. The overlap extended back into the planning stages where the organizers discussed postdoc applications with the organizers of the parallel programs, resulting in several postdocs that were in some sense joint between the programs (sometimes with joint funding, sometimes without). For example: David Shea Vela-Vick and Vera Vertesi were joint with the Homology Theories of Knots and Links program and Brett Parker was joint with the Tropical Geometry program. In addition, several of the senior personnel were considered joint between the programs. Some notable examples of this are Ko Honda and Cliff Taubes.

A prime example of the interactions between the programs was the "Sutured Manifolds and the Contact Category" informal working group, where deep connections between sutured Heeegaard-Floer theory (represented by the HTKL program) and contact geometry (represented by the SCGT program) were explored. Very related to this was Vincent Colin, Paolo Ghiggini and Ko Honda's, and independently Cagatay Kutluhan, Yi-Jen Lee and Clifford Henry Taubes', breakthrough concerning the equivalence of Embedded Contact Homology and Heegaard-Floer Homology (and hence Seiberg–Witten–Floer Homology, via earlier work of Taubes and Hutchings). This beautiful work establishes the long conjectured equivalence of Seiberg-Witten Floer Homology and Heegaard-Floer Homology using subtle ideas form symplectic and contact geometry.

These are just a few of the many collaborations between the programs. Other example can be discerned from the discussions above concerning the work of the postdocs, the seminars, working groups and research highlights.

9 Nuggets and breakthrough

In the last 10 years, a lot of effort in low-dimensional topology has been directed towards understanding relations between different homology theories that are defined using completely different tools and ideas. For instance, the Seiberg-Witten homology theory, mathematically constructed by Kronheimer and Mrowka, uses some physical ideas from gauge theory; while two other theories, the Heegaard homology theory of Ozsváth and Szabó, and the Embedded Contact Homology Theory of Hutchings and Taubes, are based on ideas from symplectic geometry (Lagrangian intersection theory and holomorphic curves). Each of these approaches has its advantages, tools and corollaries. It was long conjectured that all these theories coincide. It is a major success of the current program, in interaction with the concurrent program on Homology Theories for Knots and Links, that this equivalence has been finally established.

This shows that three very different ways of constructing 3 and 4 dimensional manifold invariants, based on solving quite different kinds of PDEs, in the end give the same information. The proofs, by Kutluhan–Lee–Taubes and Colin–Ghiggini–Honda, are both very concrete and geometric, but quite different in flavor. These results already have already a lot of remarkable consequences and will undoubtedly bring many more exciting new developments.

An amazing new connection between symplectic topology and number theory was discovered in the work of McDuff and Schlenck, in the problem of symplectic packing of ellipsoids. Combining this approach with the progress in Embedded Contact Homology theory by Hutchings during the program, McDuff recently proved Hofer's conjecture about symplectic embeddings of ellipsoids.

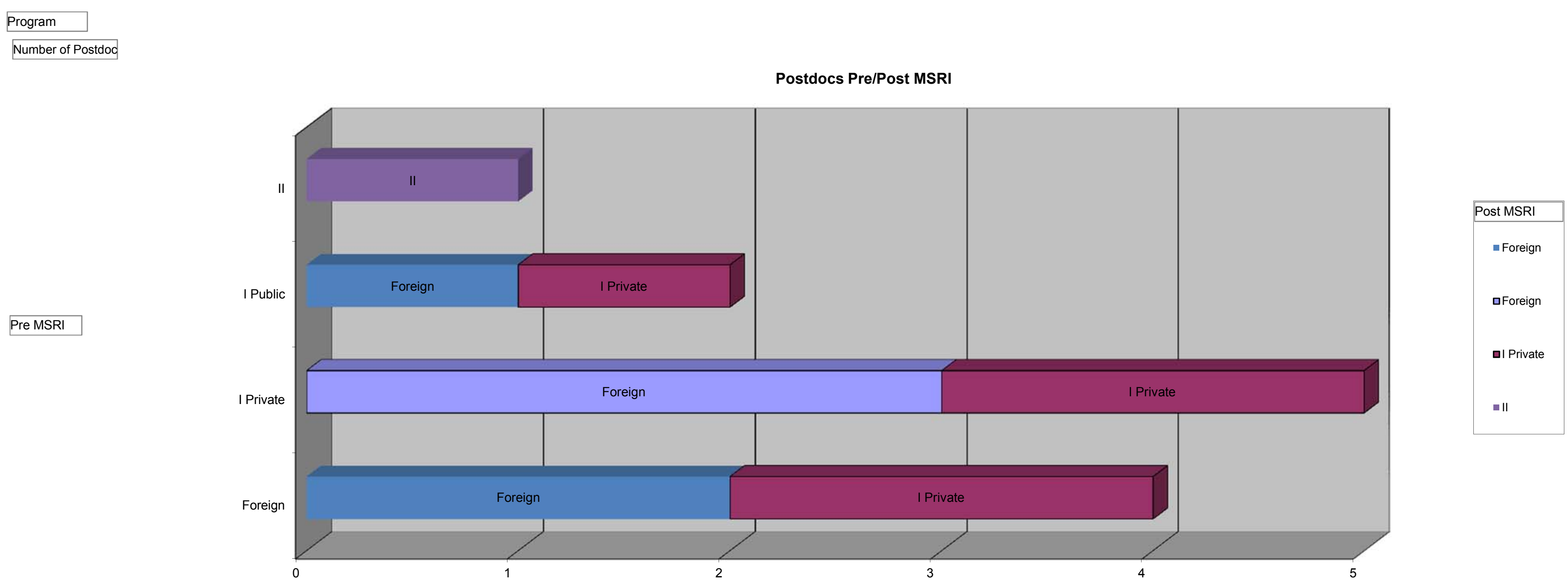
New work by Abouzaid–Seidel and by McLean shows that there are uncountably many distinct convex-at-infinity symplectic structures on Euclidean spaces of dimension at least 6, and more generally on any affine algebraic manifold. This supports Donaldson's idea that phenomena occurring in smooth 4-dimensional geometry (such as the existence of uncountably many distinct smooth structures on Euclidean 4-space, due to Gompf) should persist in higher dimensions in the symplectic category.

Symplectic geometry plays an important role in current developments in other areas of Mathematics and Physics, notably string theory and (through the work of Kapustin and Witten) the Geometric Langlands Program. One significant result obtained during the MSRI program was Smith's description of the Fukaya category of a particular manifold, important in gauge theory and mirror symmetry. This represents a first milestone towards a program that had been envisaged a long time ago by Segal, Donaldson and Fukaya. Conversely, ideas from string theory (mirror symmetry for Landau-Ginzburg models) have had strong implications in symplectic topology, in the work of Fukaya–Oh–Ohta–Ono and others (McDuff, Woodward) on Lagrangian non-displacement problems.

In the words of one program participant, there was "too much exciting stuff going on" at any time. This attests both to the general healthy state of developments in the area, and to the strong positive effect that the MSRI program has had on it.

Symplectic and Contact Geometry and Topology
Postdoctoral Fellows Pre/Post MSRI
Institution Groups based on AMS classification

				Institute				AMS Groups		
Activity	*Family Name*	*First Name*	*Year Ph.D.*	*Degree*	*Pre MSRI*	*Placement/Post MSRI*	*Position*	*Degree*	*Pre MSRI*	*Post MSRI*
Symplectic and Contact Geometry and Topology	Buhovski	Lev	2009	Tel Aviv University	Tel Aviv University	University of Chicago	Postdoc	Foreign	Foreign	I Private
Symplectic and Contact Geometry and Topology	Fabert	Oliver	2008	University of Munich	Ludwig-Maximilians-Universität München	Max Planck Institute	Researcher	Foreign	Foreign	Foreign
Symplectic and Contact Geometry and Topology	Gadbled	Agnès	2008	Universite Louis Pasteur de Strasbourg	Universite de Neuchatel	Universite de Neuchatel	Postdoc	Foreign	Foreign	Foreign
Symplectic and Contact Geometry and Topology	Golovko	Roman	2009	USC	USC	Universite de Montreal	Researcher	I Private	I Private	Foreign
Symplectic and Contact Geometry and Topology	He	Jian	2006	Stanford University	USC	Universite Libre de Bruxelles	Postdoc	I Private	I Private	Foreign
Symplectic and Contact Geometry and Topology	Kutluhan	Cagatay	2009	University of Michigan, Ann Arbor	University of Michigan, Ann Arbor	Columbia University	Assistant Professor	I Public	I Public	I Private
Symplectic and Contact Geometry and Topology	Lekili	Yanki	2009	MIT	MIT	University of Cambridge	Junior Research Fellow	I Private	I Private	Foreign
Symplectic and Contact Geometry and Topology	Ma'u	Sikimeti	2008	Rutger University, New Brunswick	MIT	Barnard College	Postdoc	I Public	I Private	I Private
Symplectic and Contact Geometry and Topology	McLean	Mark	2008	University of Cambridge	MIT	MIT		Foreign	I Private	I Private
Symplectic and Contact Geometry and Topology	Parker	Brett	2005	Stanford University	UC Berkeley	University of Zurich	Postdoc	I Private	I Public	Foreign
Symplectic and Contact Geometry and Topology	Savelyev	Yakov	2008	SUNY Stony Brooks	University of Massachusetts, Amherst	University of Massachusetts, Amherst	Postdoc	I Public	II	II
Symplectic and Contact Geometry and Topology	Vertesi	Vera	2009	Eotvos University	Alfred Renyi Institute of Mathematics	MIT	Postdoc	Foreign	Foreign	I Private



Symplectic and Contact Geometry and Topology

Program Summary

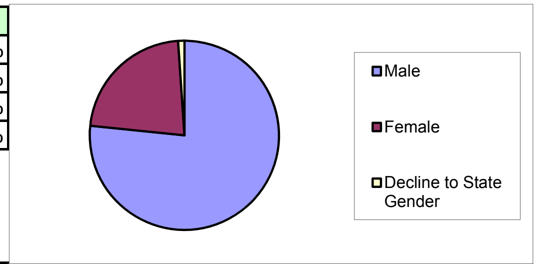
Role	# of Distinct Members	%	# of Citizens & Perm. Res.	%	# of Female	%	# of Minorities	%
Organizers	5	*5.3%*	5	*100.0%*	2	*40.0%*	0	*0.0%*
Research Professors	16	*17.0%*	10	*62.5%*	0	*0.0%*	0	*0.0%*
Postdoctoral Fellows	12	*12.8%*	3	*25.0%*	3	*25.0%*	1	*33.3%*
PD/RM	2	*2.1%*	2	*100.0%*	0	*0.0%*	0	*0.0%*
Research Members	49	*52.1%*	24	*49.0%*	14	*28.6%*	0	*0.0%*
Program Associates	10	*10.6%*	3	*30.0%*	2	*20.0%*	0	*0.0%*
Guests	0	*0.0%*	0	*0.0%*	0	*0.0%*	0	*0.0%*
Total no. of Distinct Members	**94**	**100.0%**	**47**	**50.0%**	**21**	**22.3%**	**1**	**2.1%**

Home Institute Grouping

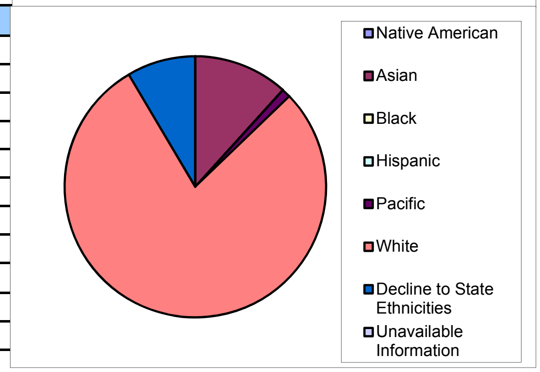
Role	Foreign	Group I Private	Group I Public	Group II	Group III	Group M	Non-Group	Total
Organizers		4	1					5
Research Professors	6	3	6	1				16
Postdoctoral Fellows	7	3	2					12
PD/RM		2						2
Research Members	23	13	6	2	2	1	2	49
Program Associates	2	7	1					10
Total	**38**	**32**	**16**	**3**	**2**	**1**	**2**	**94**
%	***40.4%***	***34.0%***	***17.0%***	***3.2%***	***2.1%***	***1.1%***	***2.1%***	***100.0%***

Symplectic and Contact Geometry and Topology Demographic Summary

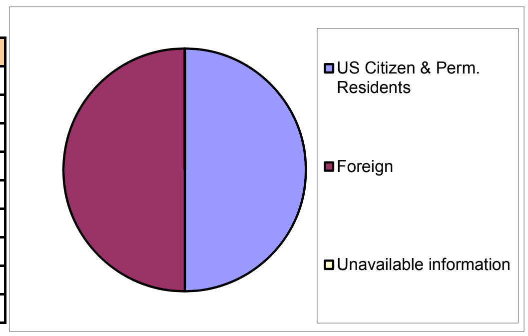
Gender	#	% (No Decl.)*	%
No. of Distinct Members	94		100.0%
Male	72	77.42%	76.6%
Female	21	22.58%	22.3%
Decline to State Gender	1		1.1%



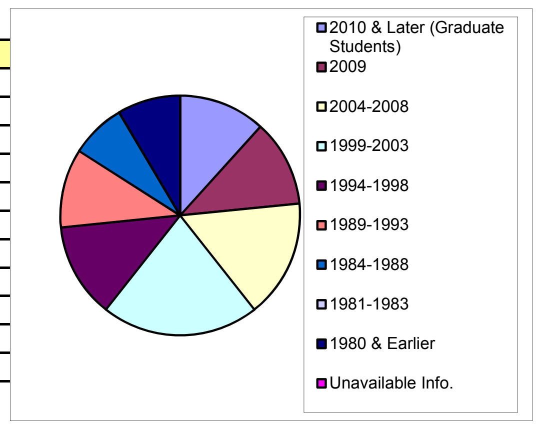
Ethnicities	#	% (No Decl.)*	%
Native American	0	0.00%	0.0%
Asian	11	12.79%	11.7%
Black	0	0.00%	0.0%
Hispanic	0	0.00%	0.0%
Pacific	1	1.16%	1.1%
White	74	86.05%	78.7%
Decline to State Ethnicities	8		8.5%
Unavailable Information	0		0.0%
No. of Distinct Members	94		100.0%
Minorities	1		2.1%



Citizenships	#		%
US Citizen & Perm. Residents	47		50.0%
Foreign	47		50.0%
Unavailable information	0		0.0%
No. of Distinct Members	94		100.0%
US Citizen	33		35.1%
Perm Residents	14		14.9%
Home Inst. in US	56		59.57%



Year of Ph.D	#		%
2010 & Later (Graduate Students)	11		11.7%
2009	11		11.7%
2004-2008	15		16.0%
1999-2003	20		21.3%
1994-1998	12		12.8%
1989-1993	10		10.6%
1984-1988	7		7.4%
1981-1983	0		0.0%
1980 & Earlier	8		8.5%
Unavailable Info.	0		0.0%
Total	94		100.0%



REPORT ON THE MSRI WORKSHOP "HOMOLOGY THEORIES OF KNOTS AND LINKS"

Organizers

- Mikhail Khovanov (Columbia University)
- Peter Ozsváth (Columbia University)
- Lev Rozansky (UNC)
- Zoltán Szabó (Princeton University)
- Dylan Thurston (Columbia University/Barnard)

1. Scientific description

Link homology is a new source tools for studying low-dimensional phenomena. Although its goal is to explore the topology of familiar low-dimensional objects – knots, links, and indeed three- and four-manifolds – this rapidly-developing subject draws on many seemingly unrelated branches of mathematics. The field is driven primarily by three currents in mathematics: representation theory, gauge theory, and symplectic geometry. These three currents have lead, respectively, to Khovanov homology and other "categorifications"; forms of gauge-theoretic Floer homology including instanton Floer homology (using anti-self-dual connections), and more recently Floer homology for Seiberg-Witten monopoles; and finally, Heegaard Floer homology, along with its other variants for knots, links, and sutured manifolds.

This new discipline is at a critical moment in its development. Categorification has seen a broad expansion as a subject. It is now solidly linked to homological algebra of rings and differential graded rings. Relations have been found between link homology and algebraic geometry, including derived categories of sheaves on suitable quiver varieties and convolution varieties in affine Grassmannians. A more direct connection between categorification and the Langlands program is likely to be found in the near future.

Various calculational techniques have rendered aspects of Heegaard Floer homology to be combinatorially describable (a goal which has so far eluded its gauge-theoretic predecessors). Various relationships have been discovered relating categorifications with their more geometrically-defined cousins (typically formulated as spectral sequence from categorified invariants to gauge-theoretic or symplectically defined invariants). Finally, continuing the thread unifying gauge theory and symplectic geometry initiated by Taubes (in his proof that Seiberg-Witten invariants count certain Gromov invariants), the close relationship between Heegaard Floer homology and Seiberg-Witten theory is well on its way from being a conjecture to a theorem. In addition to these various exciting developments within the subject of link homology, the subject continues to interact with classical questions in low-dimensional topology, shedding new light on and solving old problems.

The aim of this program was both to explore progress within these three streams, but also to study their interactions. It also benefitted greatly from its interactions with the symplectic geometry program.

Owing in part to its richness and its promise as a new tool in low-dimensional topology, link homology has attracted a large number of talented young mathematicians. Thus, the program, bringing together these young researchers from all over the world, along with the leaders in the field, proved to be beneficial both to the professional development of those young researchers, and to to the development of the subject.

2. Introductory workshop

The program began with a Connections to Women" workshop (Jan 21-22nd), organized by Elisenda Grigsby, Olga Plamenevskaya, and Katrin Wehrheim. The program Survey talks in the mornings will placed Khovanov and Heegaard Floer homology in a broader context, focusing on both their applications to classical questions in low-dimensional topology, and also connections to contact and symplectic topology. Research talks in the afternoons will highlight the range of current activity in the field. Speakers were (in chronological order): Eli Grigsby, Dusa McDuff, Heather Russel, Carmen Caprau, Shelley Harvey, Gordana Matić, Vera Vértesi, Joan Licata, Ina Petkova, and Sinem Onaran. Lectures included "Introduction to Floer Theory" (by McDuff) "Contact Invariants in Heegaard Floer homology"(Matić), and "Introduction to knot homology theories and categorification" (Grigsby).

This was followed by an introductory workshop (Jan 25-Jan 29th). oragnized by Aaron Lauda, Robert Lipshitz, and Dylan Thurston. This workshop had three mini-courses: one knot Floer homology and related topics, another on Khovanov and Khovanov-Rozansky homology; and the third on categorification of quantum groups. There were several stand-alone lectures in addition. For the mini-course on Heegaard Floer homology, the speakers were Matt Hedden, Lenhard Ng, and András Juhász. For the mini-course on Khovanov and Khovanov/Rozansky homology, the speakers were Scott Morrison and Ben Webster. For the mini-course on Categorication of Quantum Groups, the speakers were Sabin Cautis and Aaron Lauda.

We plan a format of no more than four talks each day to allow ample time for presentation opportunities for younger researchers and formal and informal discussions.

3. Presentations and Seminars

The program included a post-doc seminar, and a research seminar, several learning seminars (including a "Bordered Floer homology seminar working group") and a graduate students' seminar. These seminars benefitted greatly from their interactions with the year-long program in symplectic geometry, with several of these working groups and seminars attracting participants from both programs. Tomasz Mrowka gave a mini-course on his recent work with Peter Kronheimer, proving that Khovanov homology detects the unknot.

4. Highlights from workshops

The workshop started with a focus on developments within categorification.

Ben Webster talked about his recent remarkable categorification of Reshetikhin-Turaev invariants of links and tangles associated to arbitrary simple Lie algebras. To a simple Lie algebra and a tensor product of its irreducible representations he assigns a ring categorifying this tensor product, and to a tangle - a functor between derived categories of modules over these rings. On the Grothendieck group these functors descend to Reshetikhin-Turaev invariants. His construction utilizes an earlier work of Khovanov and Lauda on categorification of positive halves of quantized universal enveloping algebras and should have far-reaching implications for the development of representation theory and low-dimensional topology.

Lev Rozansky explained his research with Anton Kapustin on a novel structure associated to a holomorphic symplectic manifold which appears to be a sort of categorification of the Fukaya-Floer category of the manifold restricted to holomorpic lagrangian submanifolds. Catharina Stroppel talked about her joint work with Igor Frenkel and Joshua Sussan on categorification of 3j-symbols. The goal here is to categorify the entire fine structure of representation theory of quantum sl(2) paving the way for categorification of Witten-Reshetikhin-Turaev invariants of 3-manifolds. Aaron Lauda gave an overview of his categorification of the idempotented form of quantum sl(2). Lauda's 2-category is presented via an amazing graphical calculus incorporating cohomology of flag varieties, isotopies of planar diagrams and biadjoint functors. It has basic fundamental structure and is expected to act on all interesting categorifications of quantum sl(2) representations. Pedro Vaz explained a kind of dimensional reduction allowing to encode part of 3-dimensional sl(N) foam theory (which gives rise to categorification of the HOMFLYPT polynomial) via 2-dimensional objects, which happen to give Elias-Khovanov diagrammatics for the Soergel category, a categorification of the Hecke algebra. Louis Kauffman spoke about possible applications of link homology to quantum computation.

There were several talks which dealt with applications of new techniques to older questions in topology. In this vein, Joshua Greene (Columbia) presented some exciting recent developments in the lens space realization problem, enumerating all lens spaces which are obtained as surgeries on knots in the three-sphere. This question first arose in a purely classical context (Dehn surgeries on knots in the three-sphere), but its solution uses tools from both Heegaard Floer homology and Donaldson theory (gauge theory). In a different classical application of the theory, Sucharit Sarkar discussed how sutured Floer homology can be used to distinguish different Seifert surfaces for a fixed knot in S^3. John Baldwin discussed how an algebraic structure in link Floer homology – a comultiplication – gives infinitely many new examples of prime link types which are not transversally simple.

Other talks focused on new developments within the various fields. In this spirit, Robert Lipshitz (Columbia) presented aspects of *bordered Floer homology*, a new invariant for three-manifolds with boundary (defined in joint work with Ozsváth and Thurston) which is closely connected to Heegaard Floer homology. Specifically, he discussed how knot Floer homology could be obtained as the Hochschild homology groups of bimodules defined in the theory. Bordered Floer homology was further discussed by Denis Auroux, in a lecture where he gave an interpretation of this new invariant in terms of Fukaya categories of the symmetric product of a Riemann surface. In a related direction, Tim Perutz discussed an invariant counting Lagrangian correspondences which is expected to give another Heegaard-Floer theoretic invariant for three-manifolds with boundary.

Jacob Rasmussen (Cambridge) described the relationship between the maps induced by contact structures in sutured Floer homology, and four-manifold invariants gotten by counting pseudo-holomorphic triangles.

One trend within Heegaard Floer homology is its combinatorialization. Talks which explored this included lectures by András Stipsicz (Rényi Institute, Budapest) and Zoltán Szabó (Princeton) focusing on a combinatorial formulation of a version of Heegaard Floer homology, and its Similarly, Ciprian Manolescu discussed a combinatorial approach to Heegaard Floer homology (joint with Ozsváth and Thurston), giving a calculation of the invariants for surgeries on links, in terms of grid diagrams for those links. relationship with Heegaard decompositions.

On Thursday, the program was complemented significantly by a colloquium talk by Mikhail Khovanov. He spoke about his joint with with Aaron Lauda on diagrammatic categorification of quantum deformations of universal enveloping algebras of Kac-Moody Lie algebras. Another very exciting development in the subject which spans two of the above named streams (though draws some impetus from the third, as well), is Kronheimer and Mrowka's theorem stating that Khovanov homology detects the unknot. This result can be thought of as a "categorification" of a famous conjecture of Jones (that the Jones polynomial detects the unknot). Both Tomasz Mrowka and Peter Kronheimer gave talks about this new theorem. Elisenda Grigsby spoke about her related joint work with Wehrli connecting sutured Floer homology and versions of Khovanov homology.

Yi-Jen Lee spoke of her joint work with Cagathay Kutluhan and Clifford Taubes which, combined with earlier work of Taubes and constructions of Michael Hutchings, may lead ultimately to a proof of the equivalence of three important theories: Seiberg-Witten theory, embedded contact homology, and Heegaard Fleor homology.

5. Mathematical developments

The MSRI program came at a very exciting crossroads for the theory, and helped to foster some breakthroughs in the subject. These include:

- Kronheimer and Mrowka's proof that Khovanov homology detects the unknot.
- Collin-Ghiggini-Honda and Kutluhan-Lee-Taubes's proof that "Embedded contact homology" (and hence, by earlier work of Hutchings and Taubes) that Seiberg-Witten homology is isomorphic to Heegaard Floer homology.
- The development of bordered Floer homology, an invariant for parametrized surfaces and three-manifolds with parameterized boundary, which can be used to compute Heegaard Floer homology for (closed) three-manifolds.
- Categorification of quantum groups and their representations (Khovanov-Lauda, Rouquier, Webster) and Webster's categorification of Reshetikhin-Turaev tangle invariants.
- Grigsby-Wehrli's discovery of a relation between sutured Floer homology and Khovanov homology.
- Development of diagrammatical algebra and its applications to TQFT and link homology.

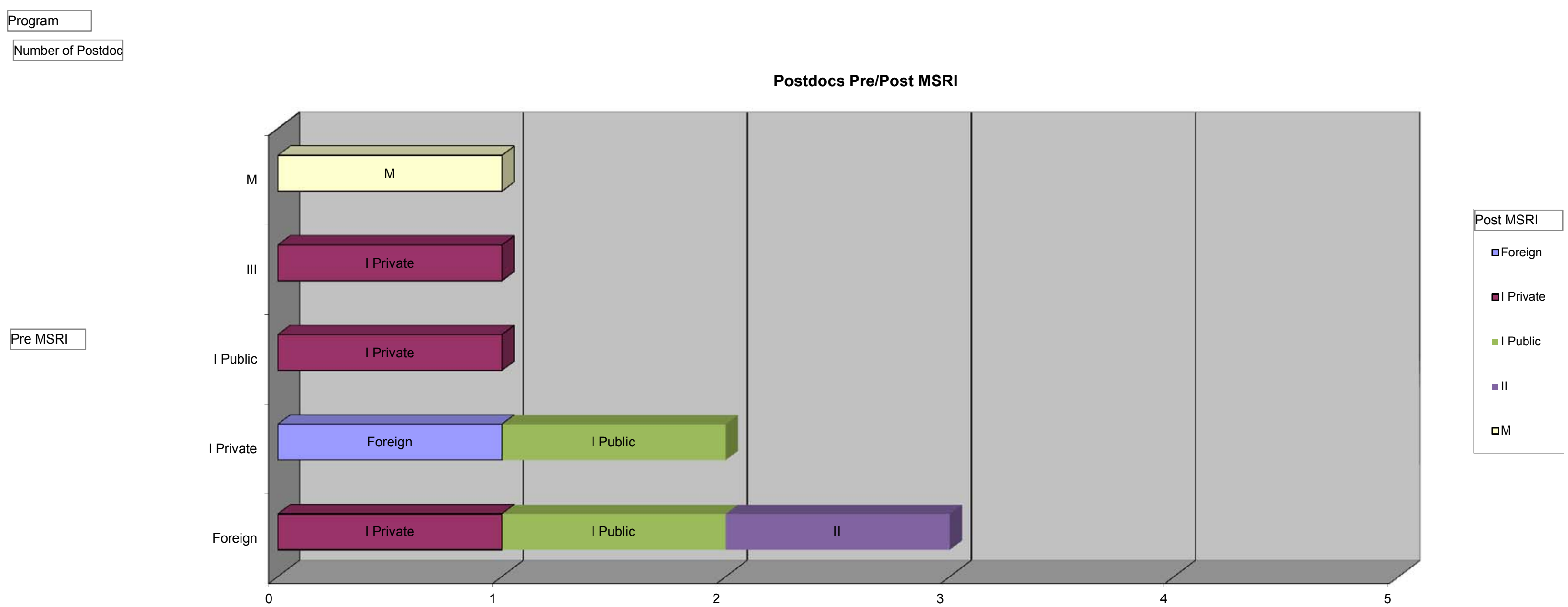
6. Post-docs

(1) **Baldwin, John.** Baldwin returned to an instructorship at Princeton Univeristy.
(2) **Greene, Joshua Evan.** Mentor: Rachel Roberts. Greene returned to his NSF post-doc position at Columbia.
(3) **Grigsby, Julia Elisenda.** Mentor: Rachel Roberts. Elisenda Grigsby began a tenure-track assistant professorship at Boston College.
(4) **Peter Douglas Horn.** Mentor: Peter Ozsváth. Horn is an NSF Postdoctoral Fellow at Columbia University.
(5) **Kutluhan, Cagatay.** (joint with Symplectic geometry) Mentor: Tomasz Mrowka. Cagatay returned to a post-doctoral position at Columbia University.
(6) **Lekili, Yankı.** (joint with Symplectic geometry) Mentor: Ko Honda. Lekili went on to a post-doctoral position in Cambridge.
(7) **Vela Vick, David Shea.** Mentor: Peter Ozsváth. Vela Vick is an NSF post-doctoral fellow at Columbia University.
(8) **Vértesi, Vera.** (joint with Symplectic geometry) Mentor: Ko Honda. Vértesi went on to a Moore Instructorship at MIT.
(9) **Wehrli, Stephan Martin.** Mentor: David Auckly. Wehri went on to a tenure-track position at SUNY Syracuse.
(10) **Krasner, Daniel.** Mentor: Thomas Mark. Krasner took a post-doctoral position at UCLA.

(11) **Lobb, Andrew Jay.** Mentor: Matt Hedden. Lobb went on to a postdoctoral position at SUNY Stony Brook.
(12) **Sucharit Sarkar.** Mentor: Peter Ozsváth. Sarkar is a Clay Fellow at Columbia University.
(13) **Sazdanovic, Radmila.** Mentor: Dylan Thurston. Sazdanovic went on to a postdoctoral position at the University of Pennsylvania.

Homology Theory of Knots and Links
Postdoctoral Fellows Pre/Post MSRI
Institution Groups based on AMS classification

				Institute				AMS Groups		
Activity	***Family Name***	***First Name***	***Year Ph.D.***	***Degree***	***Pre MSRI***	***Placement/Post MSRI***	***Position***	***Degree***	***Pre MSRI***	***Post MSRI***
Homology Theory of Knots and Links	Grigsby	Julia	2006	UC Berkeley	Boston College	Boston College	Assistant Profes	I Public	M	M
Homology Theory of Knots and Links	Kutluhan	Cagatay	2009	University of Michigan, Ann Arbor	University of Michigan, Ann Arbor	Columbia University	Assistant Profes	I Public	I Public	I Private
Homology Theory of Knots and Links	Lekili	Yanki	2009	MIT	MIT	University of Cambridge	Junior Research	I Private	I Private	Foreign
Homology Theory of Knots and Links	Krasner	Daniel	2009	Columbia	Columbia University	UCLA	Assistant Profes	I Private	I Private	I Public
Homology Theory of Knots and Links	Lobb	Andrew	2007	Harvard University	Imperial College	SUNY Stony Brook	Postdoc	I Private	Foreign	I Public
Homology Theory of Knots and Links	Sazdanovic	Radmila	2010	George Washington University	George Washington University	University of Pennsylvania	Postdoc	III	III	I Private
Homology Theory of Knots and Links	Vertesi	Vera	2009	Eotvos University	Alfred Renyi Institute of Mathematics	MIT	Instructor	Foreign	Foreign	I Private
Homology Theory of Knots and Links	Wehrli	Stephan	2007	University of Zurich	Université de Paris VII	Syracuse University	Assistant Profes	Foreign	Foreign	II



Homology Theory of Knots and Links

Program Summary

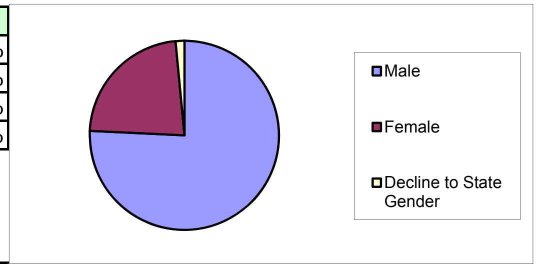
Role	# of Distinct Members	%	# of Citizens & Perm. Res.	%	# of Female	%	# of Minorities	%
Organizers	6	*9.1%*	6	*100.0%*	1	*16.7%*	0	*0.0%*
Research Professors	6	*9.1%*	4	*66.7%*	1	*16.7%*	0	*0.0%*
Postdoctoral Fellows	8	*12.1%*	3	*37.5%*	3	*37.5%*	0	*0.0%*
PD/RM	4	*6.1%*	2	*50.0%*	0	*0.0%*	0	*0.0%*
Research Members	34	*51.5%*	19	*55.9%*	6	*17.6%*	1	*5.3%*
Program Associates	8	*12.1%*	5	*62.5%*	4	*50.0%*	0	*0.0%*
Guests	0	*0.0%*	0	*0.0%*	0	*0.0%*	0	*0.0%*
Total no. of Distinct Members	**66**	***100.0%***	**39**	***59.1%***	**15**	***22.7%***	**1**	***2.6%***

Home Institute Grouping

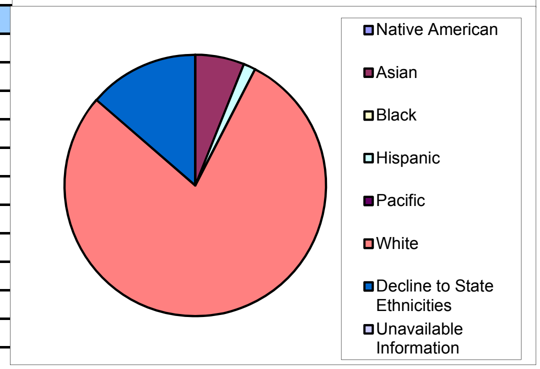
Role	Foreign	Group I Private	Group I Public	Group II	Group III	Group IV	Group M	Non-Group	Grand Total
Organizer		5				1			6
RP	3	1	2						6
Postdoc	3	1	2		1		1		8
PD/RM		4							4
Research Member	12	12	6	1	1		1	1	34
Program Associate	1	7							8
Total	**19**	**30**	**10**	**1**	**2**	**1**	**2**	**1**	**66**
%	***28.8%***	***45.5%***	***15.2%***	***1.5%***	***3.0%***	***1.5%***	***3.0%***	***1.5%***	***100.0%***

Homology Theory of Knots and Links Demographic Summary

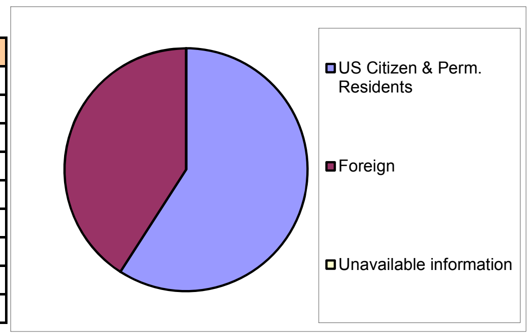
Gender	#	% (No Decl.)*	%
No. of Distinct Members	66		100.0%
Male	50	76.92%	75.8%
Female	15	23.08%	22.7%
Decline to State Gender	1		1.5%



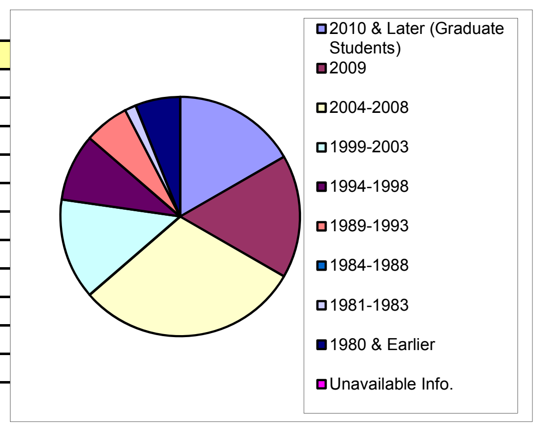
Ethnicities	#	% (No Decl.)*	%
Native American	0	0.00%	0.0%
Asian	4	7.02%	6.1%
Black	0	0.00%	0.0%
Hispanic	1	1.75%	1.5%
Pacific	0	0.00%	0.0%
White	52	91.23%	78.8%
Decline to State Ethnicities	9		13.6%
Unavailable Information	0		0.0%
No. of Distinct Members	66		100.0%
Minorities	1		2.6%



Citizenships	#		%
US Citizen & Perm. Residents	39		59.1%
Foreign	27		40.9%
Unavailable information	0		0.0%
No. of Distinct Members	66		100.0%
US Citizen	33		50.0%
Perm Residents	6		9.1%
Home Inst. in US	47		71.21%



Year of Ph.D	#		%
2010 & Later (Graduate Students)	11		16.7%
2009	11		16.7%
2004-2008	20		30.3%
1999-2003	9		13.6%
1994-1998	6		9.1%
1989-1993	4		6.1%
1984-1988	0		0.0%
1981-1983	1		1.5%
1980 & Earlier	4		6.1%
Unavailable Info.	0		0.0%
Total	66		100.0%



Statistic Calculation based on all participants that did not decline.

Mathematical Sciences Research Institute

Complementary Program

August 17, 2009 to May 21, 2010

MSRI, Berkeley, CA, USA

For scientific report from:

Severs, Christopher (Postdoc), please refer to the next page

Hillar, Christopher (Postdoc), please refer to the next program of the Appendix "Postdoctoral Program supported by the NSF Supplemental Grant DMS-0936277"

Report on Complementary Program 2009-2010

Summary
During my time in the Complementary Program (2009-2010) at MSRI I (with coauthors) submitted one journal article that was accepted for publication as well as finished the bulk of the work on two more articles which have been submitted for publication. I also submitted and had accepted a conference presentation at a major international conference (FPSAC). I was welcomed by the participants in the Tropical Geometry Program (2009) and regularly attended the seminars and smaller working group meetings during that program. After the end of the Tropical Geometry program I organized a working group with some other mathematicians who had similar interests. One of the connections I made during this time led to my next postdoctoral position at Reykjavik University.

Fall 2009
Although I was not directly part of the Tropical Geometry program, I had interest in the program and the organizers invited me to participate in the program. During this time I developed a working relationship with one of the Tropical Geometry postdocs (Benjamin Nill) and we started a project that is suitable for a future publication. I also participated in the homology working group which greatly increased my knowledge of topological combinatorics, and started to work on some problems in this area with a postdoc at U.C. Berkeley (Alex Engstrom).
During this time, I (with coauthors Hélène Barcelo and Jacob A. White) submitted a journal article to *Transactions of the American Mathematical Society*, which has subsequently been accepted for publication. Jacob A. White and I also submitted an article to the FPSAC conference which was accepted as a talk.

Spring 2010
During the Spring I worked mostly with John Shareshian, who was part of the Complementary Program, and Einar Steingrimsson, who was visiting U.C. Berkeley. I organized a weekly meeting that was also regularly attended by Hélène Barcelo and Eric Babson. These meetings led to two ongoing projects for myself, one with John Shareshian and the other with Einar Steingrimsson. While we haven't submitted any results yet, the projects have expanded my network of collaborators. In addition, my current position is as a postdoctoral researcher working with Einar Steingrimsson. I believe that my working relationship with Einar was very influential in the decision to hire me, and that had I not been at MSRI during the time when Einar was at Berkeley I would never have had the chance establish such a relationship.
During this time the bulk of the work for two more submitted papers was completed as well.

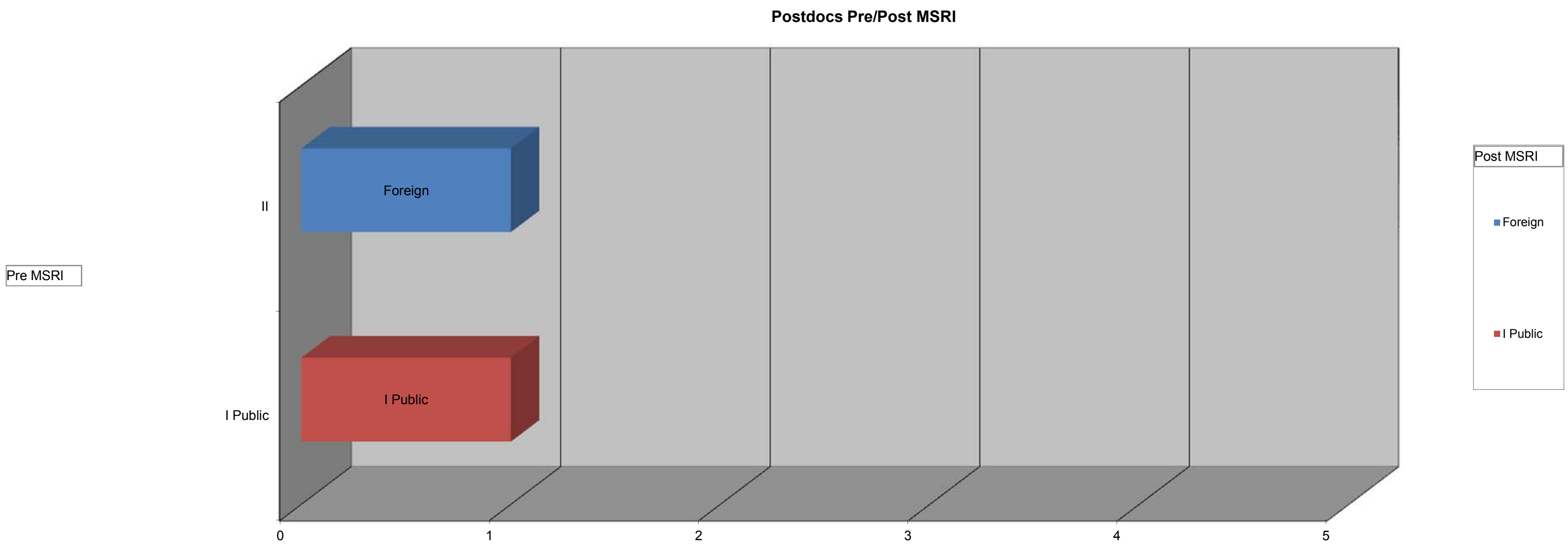
Possible Improvements
It is difficult to come up with any substantial criticisms of my experience at MSRI. One improvement that I think may be useful for postdocs in the Complementary Program is to assign them a mentor as is common in the regular programs. A suitable mentor might be found at U.C. Berkeley if none are in residence at MSRI.

Complementary Program 2009-10
Postdoctoral Fellows Pre/Post MSRI
Institution Groups based on AMS classification

				Institute				*AMS Groups*		
Activity	***Family Name***	***First Name***	***Year Ph.D.***	***Degree***	***Pre MSRI***	***Placement/Post MSRI***	***Position***	***Degree***	***Pre MSRI***	***Post MSRI***
Complementary Program 2009-10	Hillar	Christopher	2005	UC Berkeley	UC Berkeley	Redwood Center for Theoretical Neuroscience	Postdoc	I Public	I Public	I Public
Complementary Program 2009-10	Severs	Christopher	2009	Arizona State University	Arizona State University	Reykjavik University	Postdoc	II	II	Foreign

Program

Number of Postdoc



Complementary Program 2009-10

Program Summary

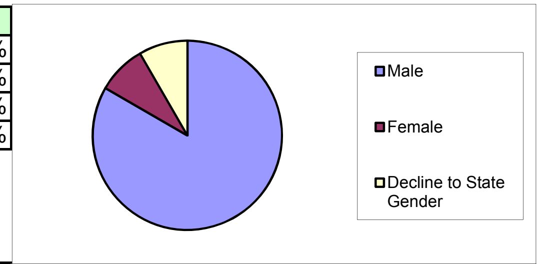
Role	# of Distinct Members	%	# of Citizens & Perm. Res.	%	# of Female	%	# of Minorities	%
Organizers	0	*0.0%*	0	*0.0%*	0	*0.0%*	0	*0.0%*
Research Professors	1	*8.3%*	0	*0.0%*	1	*100.0%*	0	*0.0%*
Postdoctoral Fellows	2	*16.7%*	2	*100.0%*	0	*0.0%*	1	*50.0%*
PD/RM	0	*0.0%*	0	*0.0%*	0	*0.0%*	0	*0.0%*
Research Members	4	*33.3%*	2	*50.0%*	0	*0.0%*	0	*0.0%*
Program Associates	0	*0.0%*	0	*0.0%*	0	*0.0%*	0	*0.0%*
Guests	5	*41.7%*	4	*80.0%*	0	*0.0%*	0	*0.0%*
Total no. of Distinct Members	**12**	***100.0%***	**8**	***66.7%***	**1**	***8.3%***	**1**	***12.5%***

Home Institute Grouping

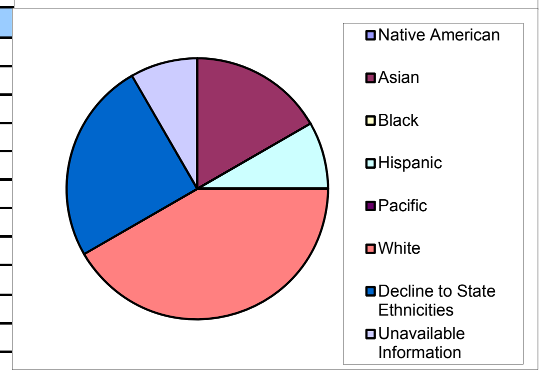
Role	Foreign	Group I Private	Group I Public	Group II	Non-Group	Grand Total
Research Professors	1					1
Postdoctoral Fellows			1	1		2
Research Members	2	2				4
Guest		3	1	1		5
Total	**3**	**5**	**2**	**2**	**-**	**12**
%	***25.0%***	***41.7%***	***16.7%***	***16.7%***	***0.0%***	***100.0%***

Complementary Program Demographic Summary

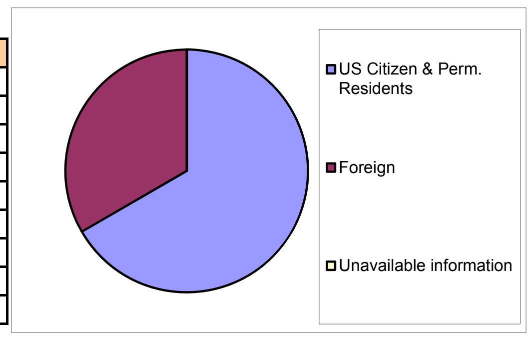
Gender	#	% (No Decl.)*	%
No. of Distinct Members	12		100.0%
Male	10	90.91%	83.3%
Female	1	9.09%	8.3%
Decline to State Gender	1		8.3%



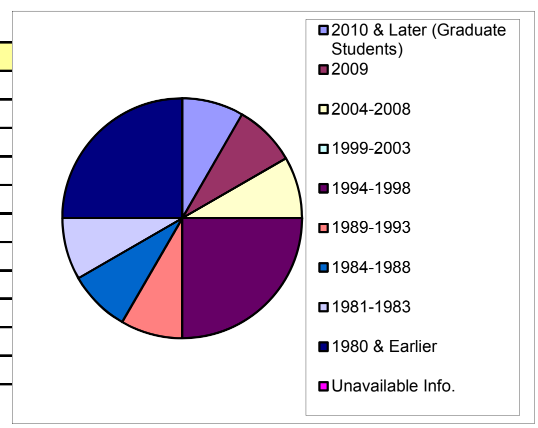
Ethnicities	#	% (No Decl.)*	%
Native American	0	0.00%	0.0%
Asian	2	25.00%	16.7%
Black	0	0.00%	0.0%
Hispanic	1	12.50%	8.3%
Pacific	0	0.00%	0.0%
White	5	62.50%	41.7%
Decline to State Ethnicities	3		25.0%
Unavailable Information	1		8.3%
No. of Distinct Members	12		100.0%
Minorities	1		12.5%



Citizenships	#		%
US Citizen & Perm. Residents	8		66.7%
Foreign	4		33.3%
Unavailable information	0		0.0%
No. of Distinct Members	12		100.0%
US Citizen	7		58.3%
Perm Residents	1		8.3%
Home Inst. in US	9		75.00%



Year of Ph.D	#		%
2010 & Later (Graduate Students)	1		8.3%
2009	1		8.3%
2004-2008	1		8.3%
1999-2003	0		0.0%
1994-1998	3		25.0%
1989-1993	1		8.3%
1984-1988	1		8.3%
1981-1983	1		8.3%
1980 & Earlier	3		25.0%
Unavailable Info.	0		0.0%
Total	12		100.0%



**Statistic Calculation based on all participants that did not decline.*

Postdoctoral Program supported by the NSF Supplemental Grant DMS-0936277

First year of grant

August 17, 2009 to May 21, 2010

MSRI, Berkeley, CA, USA

Reports from:

Angeltveit, Vigleik

Croft, Scott

Hillar, Christopher

Mahlburg, Karl

Smith, Abraham

MID YEAR REPORT - DECEMBER 2009

VIGLEIK ANGELTVEIT

In the fall semester of 2009 my main focus has been on a new project trying to understand the algebraic K-theory of $\mathbb{Z}/p^n$ for p prime and $n \geq 2$; the simplest rings for which the algebraic K-theory is not yet understood. The strategy is to use the cyclotomic trace map from $K(R)$ to the topological cyclic homology spectrum $\mathrm{TC}(R; p)$.

The main new tool is a family of spectral sequences obtained from filtering $\mathbb{Z}/p^n$ by powers of p. For topological Hochschild homology, this spectral sequence was constructed by Morten Brun, though he did not use it directly to compute $THH(\mathbb{Z}/p^n)$. By taking fixed points of $THH(\mathbb{Z}/p^n)$, we get a spectral sequence converging to $\mathrm{TR}^m(\mathbb{Z}/p^n; p)$ for each m, and together with certain structure maps this is the data needed to understand $\mathrm{TC}(\mathbb{Z}/p^n; p)$ and hence $K(\mathbb{Z}/p^n)$.

At this point I have some partial results, and I am hopeful that in the next few months I can start writing something up.

In joint work with Teena Gerhardt, we submitted the paper "On the algebraic K-theory of the coordinate axes over the integers" to Mathematical Research Letters, and we received a referee report on our paper "$RO(S^1)$-graded TR groups of $\mathbb{F}_p$, $\mathbb{Z}$ and ℓ" from the Journal of Pure and Applied Algebra indicating that our paper needs some more work to make it more accessible. My joint paper "Topological Hochschild homology of ℓ and ko" with Mike Hill and Tyler Lawson was finally accepted for publication in the American Journal of Mathematics.

After a suggestion from Chuck Weibel, Teena Gerhardt and I have also started working on trying to understand the algebraic K-theory of the group ring $\mathbb{Z}[\mathbb{Z}/2]$. This is especially interesting because it is related to diffeomorphisms of manifolds with fundamental group $\mathbb{Z}/2$, such as $\mathbb{R}P^n$.

I am still working with Mike Hill and Tyler Lawson on a continuation of our joint papers, and while progress has been slow lately I hope this will change with our scheduled visit to AIM this spring in a SQuaREs workshop. Tyler Lawson might not be able to make it, but in addition to Mike Hill, Teena Gerhardt and Andrew Blumberg will be there.

I also spent some time applying for jobs again. Although the job market is still anemic, I have already heard back from the University of Kentucky, the University of Pittsburgh, and Syracuse University.

I have been co-organizing the University of Chicago topology seminar with Michael Shulman, and I have been attending the University of Chicago proseminar, which meets twice a week. I gave talks in the Notre Dame topology seminar and the Indiana University, Bloomington topology seminar. I have met with my mentor Peter May on an "as needed" basis, meaning approximately once every two weeks.

Annual Report 2010

Vigleik Angeltveit

June 10, 2010

This is the 2010 annual report as a postdoctoral fellow with the MSRI.

The paper "Uniqueness of Morava K-theory" has been accepted for publication, pending revisions, in Compositio Mathematica. We submitted the paper "$RO(S^1)$-graded TR-groups", which is joint with Teena Gerhardt, to the Journal of Pure and Applied Algebra. We received a referee report indicating that we needed to make the paper more accessible, after which we submitted a revised version. We also submitted our paper "On the algebraic K-theory of the coordinate axes over the integers" to Mathematical Research Letters.

I have spent much of my time the last year trying to understand the algebraic K-theory of some very simple rings, like $\mathbb{Z}/p^n$. While Quillen computed the algebraic K-theory of finite fields almost 40 years ago, and Bökstedt and Madsen computed the algebraic K-theory of the p-adic integers in the early 1990s, $K(\mathbb{Z}/p^n)$ remains mysterious.

The plan is to use the cyclotomic trace map from $K(R)$ to the topological cyclic homology spectrum $\mathrm{TC}(R)$, which is built from the fixed points of the topological Hochschild homology spectrum $THH(R)$ under the action of finite subgroups of the circle. If we have a multiplicative filtration of a ring R, we get a filtration of $THH(R)$ and hence a spectral sequence computing $\pi_* THH(R)$. This filtration is S^1-equivariant, so it gives a filtration and a spectral sequence for computing the fixed points of $THH(R)$.

The case $R = \mathbb{Z}/p^n$, filtered by powers of p, is well suited for this approach. While a complete understanding of $K(\mathbb{Z}/p^n)$ is still out of reach, I believe I can at least extend the range where $K_*(\mathbb{Z}/p^n)$ is understood. In particular, I believe I can prove that for any $n \geq 2$, the first nontrivial p-torsion element $\alpha_1 \in \pi_{2p-3} S$ in the stable homotopy groups of spheres maps nontrivially to $K_{2p-3}(\mathbb{Z}/p^n)$. This was only known at the primes $p = 2$ and $p = 3$.

Charles Weibel suggested that Teena Gerhard and I try to understand the algebraic K-theory of the group ring $\mathbb{Z}[\mathbb{Z}/2]$. This would tell us about things like diffeomorphisms of manifolds with fundamental group $\mathbb{Z}/2$. Again using the cyclotomic trace map seems like a good approach, and we are able to set up spectral sequences for computing the homotopy groups of fixed points of $THH(\mathbb{Z}[\mathbb{Z}/2])$. This is still work in progress.

In March, Mike Hill, Teena Gerhardt, Andrew Blumberg and I participated in a SQuaREs workshow at the American Institute of Mathematics in Palo Alto, California. We talked about several problems related to THH and algebraic K-theory, and I think we made a lot of progress. For example, we studied THH of Thom spectra over a loop space ΩX. By work of Bökstedt, Hsiang and Madsen we understand $A(X) = K(\Sigma^\infty_+ \Omega X)$ in terms of the suspension spectrum of the free loop space on X, and the hope is that the K-theory of a Thom spectrum over ΩX will give a twisted version of $A(X)$.

REPORT FROM MENTOR
June 2010

-------- Original Message --------
Subject: Vigleik Angeltveit
Date: Sat, 12 Jun 2010 13:31:24 -0500
From: Peter May <may@math.uchicago.edu>
To: hbarcelo@msri.org

This is a brief report on Vigleik's year as an MSRI postdoc at Chicago. His mathematics is excellent, and my original letter to you probably needs no updating. He is hard at work on trying to compute the algebraic K-theory of rings Z/p^nZ. That is a project dear to my heart and has been ever since I naively gave it out as a thesis topic to a student of mine over 25 years ago. There has been little progress since, and if anybody can get anywhere on it, Vigleik can.

He and I have a joint paper in progress (my fault, not his, that progress has been slower than it should be), and he has several other deep and worthwhile projects in progress.

He is a great member of our algebraic topology (and category theory) group, which has a steady state of around seven graduate students and two postdocs. He is very helpful to the students, combining mathematical expertise and good-humored camaraderie.

He has accepted a permanent job at the Australian National University in Melbourne which, fortunately for our group, has a starting date in July, 2011. He will therefore continue to be here for all of the next academic year. He is teaching just one course, a quarter of undergraduate algebraic topology. He does a terrific job of it.

Please let me know if you would prefer a more detailed or more formal report.

Peter May
University of Chicago

EXTERNAL POSTDOCTORAL FELLOW REPORT
December 2009

-------- Original Message --------
Subject: Re: mid year report for teh NSF
Date: Tue, 22 Dec 2009 10:20:35 -0700 (MST)
From: Scott Crofts <crofts@math.utah.edu>
To: Hélène Barcelo <hbarcelo@msri.org>
References: <4B2EC1A5.90001@msri.org>

After graduating in May, my first objective was to turn the results of my thesis into a paper. After looking at things carefully, I decided to first attempt to extend the results to a more general setting. I made significant progress on this over the first few months of the summer and I now believe that this work will result in two papers. I completed the first paper and submitted it to the electronic journal 'Representation Theory'. It is a pretty long paper (~75 pages) and according to the editor, I should hear something by April. It is available on the arXiv at:

Vogan Duality for ~Spin(p,q) I - arXiv:0908.1976v1 [math.RT]

Although, I have made significant progress on the second paper, there is still more work to do there. I expect to return to this sometime next year.

Over the summer I also attended a workshop/conference on the computational representation theory of real groups. Although I did not give a talk, I was responsible for coordinating evening sessions during the workshop for graduate students.

My mentor at UCSC is Martin Weissman. Marty's research interests are similar to mine, only he works mostly over p-adic fields. Since I know very little about p-adic representation theory, I have been trying to learn as much as I can from Marty. I spent a significant amount of time trying to understand his recent paper on metaplectic tori and trying to relate it to my own work. Interestingly, we now believe that the main results of his paper do not include a case that will be important for the results of my second paper. This isn't something we understand well at this point.

Finally, I spent a week in Maryland visiting Jeffrey Adams. I gave a talk in the representation theory seminar on my own research and had a very productive visit with Jeff. I believe we have an interesting project to work on and it has already led to some nice results. I am hopeful that I can begin writing a paper on these topics early next year.

EXTERNAL POSTDOCTORAL FELLOW REPORT
June 2010

-------- Original Message --------
Subject: Re: Year 1 final report for the NSF
Date: Thu, 10 Jun 2010 13:42:39 -0600 (MDT)
From: Scott Crofts <crofts@math.utah.edu>
To: Hélène Barcelo <hbarcelo@msri.org>

Hi Helene,

Here is my end of the year report. Let me know if you need something more formal than an email.

My first year as an NSF postdoctoral fellow at MSRI was very productive. One of the main things I accomplished was generalizing the primary result in my thesis and submitting a paper to the electronic journal Representation Theory. The manuscript I submitted was very long (~75 pages) and I fully expected it to take some time to referee. I just recently received referee comments back and overall they were positive. The referee was concerned about the length and some aspects of the exposition, but I am confident I can address these issues and I am actively working to make these revisions.

In addition to working to extend the results of my thesis, I branched out in two different directions by starting work on two collaborative projects. The first is with Jeffrey Adams at the University of Maryland. We began a project to develop a two-sided parameter space for nonlinear simply laced groups expanding on the work of Fokko du Cloux. This work is related to the `Atlas of Lie Groups and Representations' project and is the potential first step for using computers to compute the unitary dual of a nonlinear group. At this point I think we have some nice results and I expect to spend time this summer writing them up.

My other collaboration is with Peter Trapa. We began a project to classify the W-cells for nonlinear indefinite unitary groups. I am happy to report we believe we have a complete answer to this question. I have begun the process of writing up this result as well. The ideas needed in the proof are very new to me, so this is taking some time, but is a great way to learn.

This year I traveled to Maryland, Utah, and AIM. I gave talks on my research at each place as well as in Santa Cruz. I was also able to teach one course at UCSC this year - a multivariable calculus course. It was a lot of work, but very enjoyable. Although it definitely slowed down my research a bit, I do think it is important to continue to teach - hopefully it will help in applying for jobs this fall.

Finally, Marty Weissman has been an excellent mentor. He has been very accommodating and has always made sure that I have the resources I need at UCSC. He is always available to bounce ideas off of or provide insight into whatever I am working on. While his research area is somewhat different than my own, it's helpful to have an alternate perspective and I look forward to continuing to learn from him.

Scott

REPORT FROM MENTOR
June 2010

-------- Original Message --------
Subject: Scott Crofts
Date: Tue, 15 Jun 2010 05:40:51 -0700
From: Martin Weissman <weissman@ucsc.edu>
To: Helene Barcelo <hbarcelo@msri.org>
CC: Chongying Dong <dong@math.ucsc.edu>

Dear Helene (cc. Chongying),

I'm writing to provide an update on Scott Crofts, who has been appointed as an MSRI postdoctoral fellow here at UC Santa Cruz for the past academic year.

It's been a pleasure talking with Scott about his research in representation theory. He has focused on two research tasks that I know of. First, and perhaps most importantly, he has spent time getting the results of his Ph.D. thesis published. This thesis, on the representations of covers of Spin groups, has been submitted to the excellent journal Representation Theory. My impression is that the lengthy paper (around 90 pages, I believe) has been refereed and commented upon -- I'm not sure if it's officially accepted yet, but the referee report was positive. My hope is that Scott can make the requested changes in a timely manner (he may have already made them over the past two weeks) to get this paper in print.

Scott has also conducted some fascinating research on Vogan duality for some non-algebraic covers of real reductive groups. Even in the relatively simple case of a quasisplit unitary group SU(2,1), there are interesting covers. This version of Vogan duality is quite mysterious to me still, and I look forward to discussing it more with him. Especially, I hope I can provide some guidance as he writes up and attempts to publish these new results.

Please don't hesitate to write if you have further questions. Thank you again for your support of Scott Crofts as a postdoctoral fellow.

best,

Marty Weissman
UC Santa Cruz

POSTDOCTORAL FELLOW REPORT
December 2009

-------- Original Message --------
Subject: end of year review
Date: Mon, 14 Dec 2009 16:42:59 -0800
From: Christopher Hillar <chillar@msri.org>
To: Robert Bryant <bryant@msri.org>, Hélène Barcelo <hbarcelo@msri.org>

Dear Helene and Robert,

I wanted to take the opportunity to let you know what has been happening for me academically in the past year. First of all, I would like to say that I cannot thank both you and the MSRI enough for all of the wonderful support in the past year. The chance to work at MSRI was life-changing and especially important given my research aspirations in mathematical neuroscience. It is challenging to work at the intersection of these two fields, and I attribute much of my ongoing success to the opportunities, encouragement, and support that MSRI has offered me.

My work this year falls into two sections: (1) Pure Mathematics and (2) Theoretical Neuroscience. As I am transitioning fields, it is important to honor my obligations to collaborators (both old and new), so I have tried to be as diligent as possible in pushing out old projects and folding in new ones.

By the way, the "Compression Between Agents" paper that I alluded to in my MSRI postdoc talk last week is [7] below. It was already accepted to the ICASSP 2010 conference, and we have intentions to push out a high-profile science journal article after the break. Also, I gave an invited talk on this work at

Agent-Based Complex Systems
IPAM (Institute for Pure and Applied Mathematics)
October 12 - 14, 2009
https://www.ipam.ucla.edu/schedule.aspx?pc=onr2009

Brief Summary of Work (references below): With the team of Sottile I have finished up a large-scale computational project on the Secant Conjecture in Schubert calculus. With Sullivant we proved the independent set conjecture in algebraic statistics using some infinite dimensional Groebner basis tools I had developed with Aschenbrenner. In "Most tensor problems are NP-Hard", L.H. Lim and I proved that a generalization of fast techniques in linear algebra to the case of higher dimensional tensors is unlikely (unless P = NP). With the team of De Loera, we explored some iterative algebraic techniques for solving hard combinatorial problems. I studied word equations solvable in terms of radicals (to be thought of as a noncommutative Abel theory) with Levine and Rhea using a blend of techniques from algebra, combinatorics, and number theory. And with Martin del Campo, we studied stabilization problems in toric algebra arising from questions in chemistry and algebraic statistics.

In theoretical neuroscience, I have studied with Sommer's group applications of sparse coding and compressed sensing to a model for bandwidth-limited communication between agents (populations of neurons). Also with Sommer (and Mehta), I have been investigating neurologically plausible circuitry for clustering and memory. These ideas will form a part of a mathematical neuroscience course I am developing with Sommer. And with PI Koepsell, I am working out the mathematics for a new phase distribution model which has applications to the analysis of the oscillatory connectivity between regions in the brain.

Please let me know if you need anything else from me.

Have a wonderful holiday!!

Best regards,
-Chris

Publications:

Pure and Computational Mathematics
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[6] (with A. Martin del Campo) Symmetric stabilization of toric ideals, submitted FPSAC 2010 (a journal article is in preparation)
www.msri.org/people/members/chillar/files/HM-InvarChainStabDec10.pdf

[5] (with L. Levine and D. Rhea) Word equations in a uniquely divisible group, submitted FPSAC 2010 (a journal article is in preparation)
www.msri.org/people/members/chillar/files/HLR-UniDivGrps-Dec10b.pdf

[4] (with J. De Loera, P. Malkin, M. Omar) Iterative algebraic algorithms for the recognition of combinatorial properties, submitted to IPCO 2010. (a journal article is in preparation)
www.msri.org/people/members/chillar/files/tenpages.pdf

[3] (with L.H. Lim) Most tensor problems are NP-Hard, submitted to STOC 2010 (a journal article version is in preparation).
www.msri.org/people/members/chillar/files/tensorNPhardFINAL-STOC10.pdf

[2] (with S. Sullivant) Finite Groebner bases in infinite dimensional polynomial rings and applications, submitted to Advances in Math.
http://arxiv.org/abs/0908.1777

[1] (with Garcia-Puente, Martin del Campo, Ruffo, Teitler, Johnson, and Sottile) Experimentation at the Frontiers of Reality in Schubert Calculus, Contemporary Mathematics, to appear.
http://arxiv.org/abs/0906.2497

In addition, I plan to finish the following project very soon:

(with A. Lauve) Uniqueness of binomial factorizations in group algebras, in progress. (very early draft)
www.msri.org/people/members/chillar/files/binfactor.pdf

Theoretical Neuroscience
----

[9] (with R. Mehta and F. Sommer) Online associative memory networks and clustering, in preparation.

[8] (with K. Koepsell) The phase distribution, in preparation.

[7] (with W. Coulter, G. Isely, and F. Sommer) Adaptive sparse coding and compressed sensing, ICASSP 2010 accepted submission (a journal article version is in preparation).
www.msri.org/people/members/chillar/files/ACS-ICASSP10.pdf

POSTDOCTORAL FELLOW REPORT
June 2010

-------- Original Message --------
Subject: Re: Year 1 final report for the NSF
Date: Wed, 16 Jun 2010 15:18:53 -0700
From: Christopher Hillar <chillar@msri.org>
To: Hélène Barcelo <hbarcelo@msri.org>

In addition to the activities I discussed in my previous email (also below), here is what has happened in Spring 2010:

(1) [April 27, 2010] Gave a talk at Microsoft and researched with Lionel Levine who was visiting there (his old advisor Yuval Peres is in the Theory Group there).

(2) [March 8, 2010] Gave a talk in Berkeley's Discrete Mathematics seminar on "Word equations in a uniquely divisible group".

(3) [March 17, 2010] Gave an accepted paper talk ICASSP 2010 Dictionary Learning for Sparse Signal Representations on "Adaptive Compressed Sensing".

(4) [May 28 2010] Gave a talk at U.C. Davis in their Algebra and Discrete Mathematics Seminar about "Equations solvable by radicals in a uniquely divisible group".

(5) Submitted the paper, "Equations solvable by radicals in a uniquely divisible group" to Acta Math.
http://www.msri.org/people/members/chillar/files/HLR-UniDivGrps.pdf

(6) Got the paper "Recognizing Graph Theoretic Properties with Polynomial Ideals" accepted to Elec. J. Comb.
http://www.msri.org/people/members/chillar/files/ejc.pdf

(7) Submitted the paper "Deciphering subsampled data: adaptive compressed sensing as a principle of brain communication" to the conference NIPS 2010.

(8) Submitted the paper, "Most tensor problems are NP-Hard, submitted extended abstract" to the conference FOCS 2010
http://www.msri.org/people/members/chillar/files/tensorNPhardApril8.pdf

Lots more still, but all still in progress... ;)

Best,
-Chris

REPORT FROM MENTOR
June 2010

Year end report 2009/2010 for Christopher Hillar

I am meeting with Chris on a weekly basis and follow his progress closely. In the first year, Chris has made great progress in acquiring a large base of knowledge about computational/theoretical neuroscience. He was quickly able to immerse in the language of theoretical/computational neuroscience, to identify mathematical problems in neuroscience and to apply his mathematics expertise to tackling them. Chris is currently involved in various research projects, in many of them as the lead scientist. He presented his project on adaptive compressed sensing on the ICASSP 2010 conference and he has a NIPS paper under review and a manuscript of a journal paper in preparation. Adaptive compressed sensing is a new theory for understanding how self-organized learning principles can enable communication across axonal fiber bundles between different brain regions. It is a perfect example for Chris' abilities to bring mathematical concepts to neuroscience, thereby opening up new routes towards identifying computations performed by the brain. Chris has given many talks about his recent work at UC Berkeley and other universities and he has given several lectures about mathematical methods to the neuroscientists at the Redwood Center. Already in this first year, Chris contributions to the Redwood center have been extraordinary. His exquisite and broad mathematical knowledge, his curiosity in new scientific problems, his ability to communicate across disciplinary borders and his didactic skills make him ideally suited for building successfully his career in theoretical neuroscience.

POSTDOCTORAL FELLOW REPORT
December 2009

I began my tenure as an NSF Math Institutes Postdoctoral Fellow in September 2009, and am currently hosted by Princeton University, with joint mentors Manjul Bhargava at Princeton and Peter Sarnak at the Institute for Advanced Study (IAS). My Fellowship is administered remotely by the Mathematical Sciences Research Institute (MSRI). I am happy to report that the support of the Math Institutes Fellowship has enabled me to complete a number of research projects, and has also facilitated the significant expansion of my research program.

Indeed, my travel schedule during the fall semester would not have been possible without the Fellowship's generous travel stipend and lack of a teaching load. My specific travel activities that were (partially) supported by the Fellowship are as follows:

Sep. 6 -- 26: Research in Pairs with Kathrin Bringmann at Oberwolfach Mathematical Research Institute.

Oct. 13 -- 21: Presentation of results at INTEGERS Conference at University of West Georgia; Algebra/Number Theory Seminar talk at Emory University.

Nov. 2 -- 6: Met with Lionel Levine at the Massachusetts Institute of Technology and discussed future collaborative research.

Dec. 2 -- 12: Lecture in Analytic Number Theory Seminar at Stanford University; Discussed collaborative work with Robert Rhoades, Stanford; Attended Career Development workshop at American Institute of Mathematics; Attended one-day event for external postdoctoral Fellows at MSRI.

Dec. 18 -- 23: Lecture at International Conference on Mock Theta Functions at SASTRA University, Kumbakonam, India.

Earlier in 2009 I began a new research program with my collaborator Kathrin Bringmann (University of Cologne, Germany) on the applications of number theory in combinatorial probability and percolation theory. Specifically, we have found that the recently developed automorphic theory of mock theta functions and hypergeometric q-series appear in a fundamental way in the study of finite-size scaling and threshold behavior for square lattice percolation models. We are planning a series of joint papers on these new results, the first of which includes the resolution of a number of open problems that we completed during our time at Oberwolfach. Furthermore, we also largely completed the construction of a new family of percolation models with similar limiting behavior, and explained the connection of these limits to certain auxiliary functions and special values of the dilogarithm. Although I was already working on these problems independently when I came to Princeton, I have also been able to meet with Michael Aizenmann, who was one of the first mathematical physicist to rigorously study such thresholds.

I have also begun working on related problems in the abelian sandpile model, and expect to complete the proof of finite-size scaling behavior in this setting within the next few months; I then plan to address some additional combinatorial questions in collaboration with Lionel Levine. In order to prove the strongest results I have used methods from both number theory and combinatorial probability, the latter of which I have been learning essentially from scratch over the past several months. I am very grateful to have had the institutional support to devote time to expanding my basic research in this way, and I am excited ton continue my work in developing new combinatorial and probabilistic applications of number theory.

Year-End Report 2009–10
NSF Math Institutes Postdoctoral Fellowship

Karl Mahlburg

1 Summary

I have had a very productive year thanks to the support of my NSF Math Institutes Postdoctoral Fellowship. I was able to attend and speak at a number of conferences and workshops, as well as to make several extended research visits with various collaborators. I also benefited greatly from being hosted at Princeton University, where there has been a constant presence of interesting visitors and speakers, thanks in part to the Special Year in Analytic Number Theory at the Institute for Advanced Study.

At the beginning of 2009, Kathrin Bringmann and I began exploring some surprising connections between integer partitions, hypergeometric q-series, automorphic forms and Ramanujan's mock theta functions, and percolation models from statistical physics. Since that time, we have successfully developed these initial observations into a full research program, with applications in number theory, combinatorial probability, and statistical mechanics. I had no prior background in many of these areas, and it has been very satisfying to learn more about these subjects while discovering their connections to number theory. Indeed, I have additionally established new interests and collaborations within combinatorial probability, notably with Alexander Holroyd and Lionel Levine on abelian sandpiles.

Looking forward to the second year of my Fellowship, I am excited to pursue the continued development of my research program in combinatorial probability and number theory, but I also hope to be more directly engaged with my mentor Manjul Bhargava. I have spent much of my time this past year simply learning new areas of mathematics, but now that I am more comfortable with these subjects, I intend to devote more energy to other aspects of number theory.

2 Professional Travel

Sep. 6 – 26, 2009 **Research in Pairs Program** at Oberwolfach Mathematical Institute, working with Kathrin Bringmann. Resulted in one completed paper, "Improved bounds on metastability thresholds and probabilities for generalized bootstrap percolation", and significant progress on other aspects of our research program.

Oct. 14 – 17, 2009 **INTEGERS Conference**, University of West Georgia. Attended conference and presented talk titled "Asymptotics for crank and rank moments."

Oct. 18 – 21, 2009 **Algebra Seminar**, Emory University. Presented talk "Asymptotics for crank and rank moments."

Dec. 3 – 5, 2009 **Informal Analytic Number Theory Seminar**, Stanford University. Presented talk "Quasimock theta functions and asymptotics for the coefficients of q-series".

Dec. 6 – 10, 2009 **Workshop on Careers in Academia**, American Institute of Mathematics.

Dec. 11, 2009 **A Day at MSRI**, for external postdocs Mathematical Sciences Research Institute.

Dec. 20 – 23, 2009 **International Conference on Number Theory and Mock Theta Functions** in Kumbakonam, India. Attended conference and presented talk "Asymptotics for crank and rank moments."

Feb. 7 – 23, 2010 **Research Visit**, University of Cologne. Worked with Kathrin Bringmann. Resulted in completed project "Convolution percolation models."

Mar. 8 – 12, 2010 **Workshop on Mock Modular Forms in Combinatorics and Arithmetic Geometry**, American Institute of Mathematics. Participated in workshop research activity, and presented talk "Partitions, probability, and percolation."

Mar. 22 – 26, 2010 **Automorphic Forms Workshop**, University of Hawaii. Attended conference and presented talk "Partitions, probability, and percolation."

May 10 – 14, 2010 **Research Visit** to Microsoft Research Theory Group. Worked with Alexander Holroyd and Lionel Levine. Presented talk in Research Seminar titled "Percolation, probability, and partitions." Resulted in partial progress on the project "Dimensional reduction and unexpected symmetries in abelian sandpiles."

3 Research activity

Papers completed and submitted:

- (with K. Bringmann) *Improved bounds on metastability thresholds and probabilities for generalized bootstrap percolation.*

Papers in preparation:

- (with K. Bringmann and R. Rhoades) *Asymptotic expansions for rank and crank moments.*
- (with K. Bringmann) *Asymptotics for partitions without k-sequences.*
- (with K. Bringmann) *Convolution percolation models.*
- (with A. Holroyd and L. Levine) *Dimensional reduction and unexpected symmetries in abelian sandpiles.*

REPORT FROM MENTOR

June 2010

Karl has been doing some very impressive work this past year. His work has focused primarily on applications of automorphic forms (particularly mock modular forms) and q-series to number theory. In this regard, he has done some fantastic work with Kathryn Bringmann, and spent much of the past year visiting her in Cologne, Germany. This has led to his already very well-received paper on asymptotic expansions for crank and rank moments. This work has taken him into some serious probability and percolation theory, as evidenced in his soon-to-appear papers with Bringmann and Mellit and then with Bringmann and Holroyd. I believe that these remarkable connections which these authors have discovered will play an important role in much work to come by these and other authors.

Karl has also kept up his strong interest in combinatorics, particularly his work relating to tilings, sandpiles, and symmetric polynomials. He has continued to do very interesting work on these problems as well.

Finally, Karl has spent a lot of time this year giving lectures all over the world, both because of the recent interest in his work, and also to secure a permanent position somewhere (with which he has succeeded). He also spent much time visiting his collaborators Bringmann at Cologne, and Folsom at Yale. The latter visit has resulted in a new work on continued fraction expansions for mock theta functions.

With best regards,

Manjul

POSTDOCTORAL FELLOW REPORT
December 2009

-------- Original Message --------
Subject: postdoc report
Date: Wed, 16 Dec 2009 13:45:11 -0500
From: Abraham D. Smith <abrahamdavidsmith@gmail.com>
To: Hélène Barcelo <hbarcelo@msri.org>

Here is my summary of my activities this semester:

From August to December 2009, my main activity was to continue my project on the geometry of hydrodynamic PDEs, producing the paper "Integrable GL(2) Geometry AND Hydrodynamic Partial Differential Equations" arXiv:0912.2789v1. In September, I gave a talk on this paper at the CIRGET Geometry and Topology Seminar at UQAM. Also, I have corresponded with Dennis The regarding generalizations and applications of this work, and our collaborative research will begin in earnest after the holidays. I have also begun initial exploration of several other branches of research in the geometry of differential equations.

Aside from pure research, I have attended many seminars and participated in weekly meetings with my mentor, Niky Kamran, and his other postdocs and graduate students. In December 2009, I attended the "Careers in Academia" workshop at AIM.

POSTDOCTORAL FELLOW REPORT
June 2010

-------- Original Message --------
Subject: MSRI NSF postdoc yearly report
Date: Tue, 1 Jun 2010 10:41:51 -0400
From: Abraham Smith <abrahamdavidsmith@gmail.com>
To: Niky Kamran <nkamran@math.mcgill.ca>, hbarcelo@msri.org

This is my report of academic activities as an MSRI NSF All-Institutes postdoctoral fellow for the 2009--2010 academic year.

From August to December 2009, my main activity was to continue my project on the geometry of hydrodynamic PDEs in 3 variables, producing the paper ``Integrable GL(2) Geometry and Hydrodynamic Partial Differential Equations" arXiv:0912.2789. In September, I gave a talk on this paper at the CIRGET Geometry and Topology Seminar at UQàM. In January 2010, this paper was submitted to Communications in Analysis and Geometry; as of June 1, I am still waiting for the referee's report.

Since the submission of that paper, I have been working on a broad generalization of that theory to PDEs in any number of variables. This theory involves the development of a new geometric structure and the corresponding invariant theory. I expect this theory to allow characterization and classification of large families of integrable hyperbolic PDEs. The existing theories of integrable hyperbolic systems are usually limited to 2 (1 space + 1 time) or 3 (2 space + 1 time), but my theory will yield results in the most physically appropriate case, 4 variables. Such PDEs frequently arise in fluid mechanics, general relativity, and various other wave equations, so this theory should have a broad impact on the understanding of many systems that are important to a variety of scientists and engineers.

Progress on this project has been steady, and I am optimistic that this work will result in an article ready for submission around September, tentatively titled ``A Geometric Framework for Hydrodynamic Integrability." In April 2010, I presented an outline of this project in a special session at the AMS Sectional Meeting in St. Paul.

Aside from my own research, I have attended many seminars in analysis and geometry and participated in weekly meetings with my mentor, Niky Kamran, and his other postdocs and graduate students. In December 2009, I attended the ``Careers in Academia" workshop at AIM. During the Winter session, I gave two talks at McGill directed at graduate students and postdocs in geometry and analysis.

Upcoming plans include the ``Differential Geometry and Application" conference in Brno in August, a lecture at Texas A&M Univ in late October, and the Texas Geometry and Topology Conference in November. At all three events, I will continue discussions with potential collaborators, most notably Dennis The, who share interest in the geometric approach of partial differential equations. It is also likely that I will visit the

University of Colorado at Boulder in the Fall semester to collaborate with Jeanne Clelland.

Finally, Francis Valiquette, Niky Kamran, and I are in the process of organizing a workshop on the geometry of PDEs to be held at CRM in Montreal during Summer 2011.

REPORT FROM MENTOR
June 2010

-------- Original Message --------
Subject: Re: MSRI NSF postdoc yearly report
Date: Thu, 17 Jun 2010 12:48:49 -0400 (EDT)
From: Niky Kamran <nkamran@math.mcgill.ca>
To: Hélène Barcelo <hbarcelo@msri.org>
CC: Abraham Smith <abrahamdavidsmith@gmail.com>

It is a great pleasure to submit the following yearly report on Abe Smith's MSRI NSF post-doc.

In his report, Abe has given a very clear account of his research activities during the year he spent at McGill. I would like to add that the paper based on his thesis, which has been submitted to Communications in Analysis and Geometry, is a superb piece of work, which takes the whole field of integrable systems of hydrodynamic type, pioneered by Novikov (and most notably developed by his student Ferapontov) onto an altogether higher plane by giving it a formulation which goes to the essence of the geometric content of integrability, and by the systematic introduction of the powerful tools provided by the theory of exterior differential systems and the method of equivalence. This has made it possible for Abe to obtain very fine classification results which would be otherwise out of reach by direct methods. I would also like to add that the project that Abe is currently working on is absolutely first-rate, and that it holds in my opinion one of the keys that will unlock the mysteries associated to the rarity of the integrability property for reasonably non-degenerate non-linear PDEs in a higher number of independent variables. I have no doubt that Abe will succeed in this endeavor. This is work that will have a long shelf life, and that will be a landmark in the evolution of the field.

I would like to conclude this report by expressing my admiration for Abe as a young mathematician and colleague. During the weekly meetings we have had over the past academic year, I have had ample opportunity to appreciate Abe's approach to research and his way of thinking about mathematics. He has the maturity, balance and capacity to go to the essential elements of a problem that one normally only encounters with established mathematicians who have been successful researchers for many years. Abe is also a model young colleague, interested in the work of his fellow post-docs and of the graduate students, always willing and ready to offer his help and advice. In many ways, he is already mentoring others. This is admirable.

With the presence of Francis Valiquette, a student of Peter Olver who is here on an NSERC post-doc, and the arrival of Nabil Khaouadji, a student of Frederic Helein, who will be coming as a CRM-ISM post-doc, I am very hopeful that Abe will continue to find a stimulating mathematical environment here at McGill, that will enable him to attain his research objectives and continue on the successful academic career that I see ahead of him. For my part, I am delighted that Abe is here with us and I would like to thank the MSRI and the NSF for having made it possible for Abe to come to McGill as a post doctoral Fellow.

Sincerely,

Niky Kamran.

MSRI Mathematical Sciences Research Institute

Postdoctoral Program supported by the NSF Supplemental Grant DMS-0936277

Second year of grant

August 16, 2010 to May 20, 2011

MSRI, Berkeley, CA, USA

Reports from:

Angeltveit, Vigleik

Bogart, Tristram

Crofts, Scott

Dochtermann, Anton

Hillar, Christopher

Katz, Eric

Mahlburg, Karl

Ma'u, Sikimeti

Smith, Abraham

Speck, Jared

MSRI POSTDOCTORAL FELLOWSHIP FINAL REPORT

VIGLEIK ANGELTVEIT

Abstract. This is the final report for my MSRI postdoctoral fellowship, August 2010 to May 2011. Section 1 contains some biographical data I have been asked to supply. Section 2 contains a summary of my research while being a postdoctoral fellow.

1. Biography

Name: Vigleik Angeltveit
Year of Ph.D: 2006
Institution of Ph.D.: Massachusetts Institute of Technology
Ph.D. advisor: Haynes Miller
Institution prior to obtaining the MSRI PD fellowship: University of Chicago
Position at that institution: Dickson Instructor (postdoc)
Mentor (if applicable): J. Peter May
Institution where you held your MSRI PD fellowship: University of Chicago
Mentor at that institution: J. Peter May
Institution (or company) where you are going next year: Australian National University
Position: Lecturer, academic level B. (Permanent position, approximately equivalent to tenure track assistant professorship.)
Anticipated lenght: Permanent

2. Research in the last two years

As a postdoctoral fellow I finished two papers that were started before the fellowship, I finished at least one paper that was started during the fellowship, and I have started several new projects that are still ongoing.

2.1. **Algebraic K-theory computations using $RO(S^1)$-graded homotopy groups.** This is a multi-paper project joint with Teena Gerhardt and/or Lars Hesselholt. The basic idea is that a sufficiently good understanding of topological Hochschild homology (THH) of a ring or ring spectrum leads to calculations in algebraic K-theory. While such calculations are extremely difficult it is worth the effort because algebraic K-theory lies in the intersection of fields such as algebraic number theory, algebraic geometry and geometric topology.

The topological Hochshild homology spectrum $THH(A)$ is a *genuine* S^1-spectrum in the sense that it is indexed on S^1-representations rather than integers. As such it, and its fixed points, have homotopy groups indexed on the real representation ring $RO(S^1)$ rather than the integers. While the calculation of $K(A)$ ultimately only depends on the integer-graded homotopy groups of $THH(A)$, the

$RO(S^1)$-graded homotopy groups of $THH(A)$ enter when trying to understand the K-theory of rings related to A, such as $A[x]/(x^n)$ or $A[x,y]/(xy)$.

The first part of this project, which is joint with Teena Gerhardt, is titled "$RO(S^1)$-graded TR-groups of $\mathbb{F}_p$, $\mathbb{Z}$ and ℓ". Most of the work was done before the start of the fellowship, but it was finished during the project and was published in the Journal of Pure and Applied Algebra in 2011. In this paper we compute certain $RO(S^1)$-graded homotopy groups of fixed points of THH of certain rings. It is, by necessity, quite intricate.

The payoff came in the follow-up paper "On the K-theory of truncated polynomial algebras over the integers", which is joint with Teena Gerhardt and Lars Hesselholt. In it, we use results of the previous paper to compute the algebraic K-groups of $\mathbb{Z}]x]/(x^n)$ (up to extensions). While this paper depends on the previous one it was actually publised earlier, in Journal of Topology in 2009.

The third paper in the series, which is joint with Teena Gerhardt and was written during the fellowship, is titled "On the algebraic K-theory of the coordinate axes over the integers" and has been accepted for publication in Homology, Homotopy and Applications.

2.2. **Algebraic K-theory of $\mathbb{Z}/p^n$.** Algebraic K-theory is a great theoretical tool, but calculations are extremely difficult. One manifestation of that is that we still do not understand the K-theory of a ring as simple as $\mathbb{Z}/p^n$. That is not for lack of trying. Shortly after Quillen computed the K-theory of all finite fields, Peter May asked one of his Ph.D. students to compute the K-theory of $\mathbb{Z}/p^2$. His student got nowhere, and had to switch to a different thesis topic. Later Morten Brun, who was Marcel Bökstedt's student, succeeded in computing topological Hochschild homology of $\mathbb{Z}/p^n$. The plan was to use this to compute K-theory, but he only succeeded in doing so through a small range of dimensions.

During the fellowship I spent much of my time attacking this problem. The basic idea is that the filtration of $\mathbb{Z}/p^n$ by powers of p has $\mathbb{F}_p[x]/(x^n)$ as associated graded, and this endows $THH(\mathbb{Z}/p^n)$ with a filtration as well. This leads to various spectral sequences which, if completely understood, would compute $K_q(\mathbb{Z}/p^n)$ for all q. Using this I have been able to compute $K_q(\mathbb{Z}/p^n)$ for $q \leq 2p-2$. This is about twice as far as Brun's calculation, and it is far enough to detect that the first p-torsion element in the stable homotopy groups of spheres maps nontrivially to the corresponding K-group. Previously this was only known for $p = 2, 3$. I also prove that all the K-groups of $\mathbb{Z}/p^n$ are finite, and that $|K_{2i-1}(\mathbb{Z}/p^n)|/|K_{2i-2}(\mathbb{Z}/p^n)| = p^{(n-1)i}(p^i - 1)$.

2.3. **Algebraic K-theory of $\mathbb{Z}[C_2]$.** This is joint work with Teena Gerhardt, following a suggestion of Weibel, and is still work in progress. The algebraic K-theory of group rings is intimately connected with geometric topology. In particular $K(\mathbb{Z}[C_2])$ tells us a great deal about diffeomorphisms of manifolds whose fundamental group is cyclic of order 2. Assuming that we understand $K(\mathbb{Z})$ (this depends on a number-theory conjecture) we already understand most of $K(\mathbb{Z}[C_2])$, the one missing piece is the 2-torsion. This can be computed from a sufficiently good understanding of $THH(\mathbb{Z}[C_2])$.

Using the idea of filtering the ring to obtain spectral sequences from §2.2 above, we get a spectral sequence which starts with $\pi_*THH(\mathbb{Z}[x]/x^2)$ and converges to $\pi_*THH(\mathbb{Z}[C_2])$. By taking the inverse limit of the fixed points under the action of

C_{2^k} as k goes to infinity (with inclusion of fixed points as the structure maps) we get another spectral sequence computing $\pi_* \lim_k THH(\mathbb{Z}[C_2])^{C_{2^k}}$.

Using calculations from our paper "$RO(S^1)$-graded TR-groups of $\mathbb{F}_p$, $\mathbb{Z}$ and ℓ" we understand the E_2-term of this spectral sequence fairly well, but we kept getting the wrong answer in cases we can understand for different reasons. Finally we figured out that this happens because the spectral sequence does not converge! In retrospect that should not be too surprising, because we built $THH(\mathbb{Z}[C_2])$ as a direct limit, and we cannot expect direct limits and inverse limits to commute.

We still have a spectral sequence converging to $\pi_* THH(\mathbb{Z}[C_2])^{C_{2^k}}$ for each k, so I am still hopeful that our method will tell us something interesting.

2.4. **Algebraic K-theory in multiple variables.** This is joint work with Teena Gerhardt, Mike Hill, and Ayelet Lindenstrauss. We do have some concrete results, but nothing is yet written up and it is still work in progress. We want to understand $K(k[x_1, \ldots, x_n]/(x_1^{a_1}, \ldots, x_n^{a_n}))$, which we can do if we understand THH of that ring sufficiently well.

By a straightforward generalization of previous work of Hesselholt and Madsen we can write THH as the iterated cofiber of a certain n-cube of easier-to-understand spectra. The key observation is that this is actually an n-cube of cyclotomic spectra, which essentially means that the K-theory is given by taking the iterated cofiber of a related n-cube of spectra.

If $k = \mathbb{F}_p$ and p does not divide any of the a_i's we can compute the K-theory groups explicitly. Similarly, if $k = \mathbb{Z}$ we can compute the rationalized K-theory groups explicitly.

Our hope is that there is some underlying structure, a generalized Witt vector construction, which gives a unified description of the K-groups in all cases. But that part is still work in progress.

2.5. **Structured Quartet Research Ensemble.** The American Institute of Mathematics (AIM) has a program called SQuaRE which allows a small group to meet to work on a specific program. During the fellowship period (and immediately after) I met Andrew Blumberg, Teena Gerhardt, and Mike Hill twice at AIMs center inside Fry's electronics store in Palo Alto, and once in Chicago to work on "algebraic K-groups".

One of the problems we were interested in is that of algebraic K-theory of Thom spectra. Given a loop map $f : X \to BF$, where BF classifies stable spherical fibrations, we get a ring spectrum $Th(f)$. In previous work Andrew Blumberg and coauthors developed a good model of $THH(Th(f))$ as a spectrum. However, to be able to approach $K(Th(f))$ we need to understand $THH(Th(f))$ as a genuine S^1-spectrum.

After some early missteps, we believe we now have such a model of $THH(Th(f))$ as a genuine (indeed cyclotomic) S^1-spectrum. In the course of our work we believe we also managed to came up with a better model of THH of a commutative ring spectrum as the left adjoint of the forgetful functor from commutative genuine S^1-spectra to commutative ring spectra. This is important because the current model of THH as a cyclotomic spectrum is rather complicated and not very conceptual. Since nothing has yet been written down this is still work in progress.

MSRI POSTDOCTORAL FELLOWSHIP REPORT FOR VIGLEIK ANGELTVEIT

J. PETER MAY

Vigleik has been a mainstay of the program in algebraic topology at the University of Chicago for the past five years. He has been the main organizer and a key participant in our seminars, both those with internal and those with external speakers. He has been hugely helpful in helping me mentor graduate students. Nine students of mine obtained their PhD's in the five years since his arrival, three of them winning NSF postdoctoral fellowships. Vigleik has been a positive influence on all of them and on five other graduate students still working with me. For example, he has given masterly introductions to spectral sequences which have really taught my students how to use them.

Vigleik is a master of deep calculation and conceptual understanding. His calculations in and around algebraic K-theory, THH (Topological Hochschild Homology) and TC (Topological Cyclic homology) are quite incredibly difficult and very illuminating. I am especially impressed with his recent work with Teena Gerhardt which uses calculations of $RO(G)$-graded homotopy groups to obtain information about the non-equivariant algebraic K-theory of certain rings. I am also very impressed by the progress he has made on computing the algebraic K-theory of the rings $\mathbf{Z}/p^n$. When $n = 1$, this is of course given by Quillen's calculations of the K-theory of finite fields, around 30 years ago. For $n \geq 2$, little or no progress was made in all the time since then, until Vigleik's impressive new work.

I am very grateful that his fellowship has made it possible for him to stay in Chicago the past two years. His presence has been invaluable.

MSRI FELLOWSHIP FINAL REPORT

TRISTRAM BOGART

1. Basic Information

Your Name: Tristram Bogart
Year of Ph.D: 2007
Institution of Ph.D.: University of Washington
Ph.D. advisor: Rekha R. Thomas

Institution prior to obtaining the MSRI PD fellowship: Queen's University, Canada
Position at that institution: postdoctoral fellow
Mentor: Gregory G. Smith

Institution where you held your MSRI PD fellowship: San Francisco State University (SFSU)
Mentor at that institution: Federico Ardila

Institution where you are going next year: Universidad de los Andes, Colombia
Position: assistant professor
Anticipated length: tenure-track

2. Research

I worked on three research projects during my year at SFSU, each of which I briefly describe below. The three projects are not directly related, but they share a common theme of connecting algebra or algebraic geometry to the theory of convex polytopes. I completed the first project, am currently writing up the second and plan to submit it in summer 2011, and am in the early stages of the third.

(1) *Obstructions to lifting tropical curves in hypersurfaces*: I began this joint project with fellow MSRI postdoc Eric Katz during the tropical geometry semester in fall 2009 and we submitted our paper [BK] in January 2011. In very general terms, tropicalization is a procedure that turns an algebraic variety into a polyhedral complex, which is a piecewise-linear object that can be studied by computational and combinatorial methods. The tropical lifting problem asks for conditions under which the procedure can be reversed. The problem is quite difficult and obstructions have been found in several cases, including linear spaces and curves. In our paper we develop a new local obstruction to lifting *pairs* of tropical varieties, one embedded in another.

(2) *Mapping polytopes*: In this project with SFSU professor Joseph Gubeladze and former student Mark Contois, we study the construction of mapping polytopes. This construction is key to developing a categorical theory of polytopes that includes homomorphims (affine maps), direct products, tensor products, and more. Given full-dimensional polytopes $P \subseteq \mathbb{R}^n$ and $Q \subseteq \mathbb{R}^m$, the mapping polytope is simply the set of affine linear maps $\Phi : \mathbb{R}^n \to \mathbb{R}^m$ satisfying the property that $\Phi(P) \subseteq Q$. This set is itself a polytope of dimension $(n+1)m$

Date: May 31, 2011.

and its facets are known [Zie95], but otherwise it is little-understood. We verify several categorical properties, prove a structural result in the case where (P, Q) is a pair of generic polygons, and compute several families of examples.

(3) *Properties of Smooth Lattice Polytopes* An important reason for studying (lattice) polytopes is their connection to toric geometry. Among the properties of a projective toric variety X that are determined by its lattice polytope P are whether
  (a) X is smooth: if and only if the primitive edge directions at each vertex of P form a lattice basis,
  (b) X is normal (integrally closed): if and only if the lattice points in $(P, 1) \subset \mathbb{R}^{n+1}$ generate the monoid of lattice points in the cone over P, and
  (c) the ideal of X has a square-free quadratic initial ideal: if and only if P possesses a regular unimodular triangulation.

It is known that (1) $\Longrightarrow$ (2) $\Longrightarrow$ (3), but it is unknown whether (2) or (3) implies (1). This question was the subject of a workshop I attended at the American Institute for Mathematics in 2009 and I was among a group of participants that wrote a paper [BHH$^+$] verifying the reverse implications for lattice three-polytopes with up to 12 lattice points.

My mentor Federico Ardila, along with Florian Block, introduced a new construction of polytopes in [AB]: given any d-polytope P and any partition λ with d parts, there is a polytope P^λ that surjects onto P with each fiber being a product of simplices $\Delta_{\lambda_1} \times \cdots \times \Delta_{\lambda_d}$. If P is smooth then so is P^λ for any λ. Our current project is to show that the other properties carry over from P to P^λ. In particular, we can show that normality carries over, and we are currently working regular unimodular triangulations.

3. Travel

With the help of MSRI travel funding, I was able to present the tropical lifting result at a conference in Osaka, Japan and at seminars in Saarbrücken, Germany and in Davis, California. I also gave a colloqium talk at Sonoma State University and research talks on other topics at Bay Area Discrete Mathematics Day (BADMath Day) 22 at MSRI and at a Society for Industrial and Applied Mathematics conference on optimization in Darmstadt, Germany. I attended the Canadian Mathematical Society winter meeting in Vancouver and will attend and speak at the CMS summer meeting in Edmonton.

4. Teaching and Mentoring

In fall 2010, I taught a section of calculus I at San Francisco State with 35 students and one teaching assistant. Teaching this material was not new for me, but San Francisco State is a little different in its unusually diverse student population. There are many non-traditional students who haven't taken a math class in many years. Helping these students keep up was a challenge, but a rewarding one.

I also assisted Prof. Ardila in his graduate course on polytopes and discrete geometry by giving two lectures, answering questions, and helping a pair of students on their final project, related to my work on mapping polytopes.

Along with Prof. Matthias Beck, I coadvised a masters' thesis on Goulomb rulers. Goulomb rulers arise in number theory (of which I know little) but the project was to study them using discrete geometry. Specifically, the set of such rulers with fixed parameters is enumerated by the set of lattice points that lie inside a polytope but not on any of a collection of hyperplanes. The student created a new type of labelled graphs that index the regions of this hyperplane arrangement.

5. Service

I served as the local organizer for BadMath Day 23, which took place at SFSU on April 30, 2011. BadMath Day is a one-day free conference that aims to introduce a variety of research topics in discrete mathematics to students around the region and to facilitate communication among mathematicians and students at all levels. The recent conference featured four half-hour talks and two one-hour talks and was attended by 63 people, about two-thirds of them students.

I also coorganized and regularly attended the Algebra-Geometry-Combinatorics seminar at SFSU, and assisted Ardila and Beck in organizing the larger conference Formal Power Series and Algebraic Combinatorics (FPSAC) '10, held on August 2-6, 2010 at SFSU.

References

[AB] Federico Ardila and Florian Block. Universal polynomials for severi degrees of toric surfaces. arXiv:1012.5305.

[BHH$^+$] Tristram Bogart, Christian Haase, Milena Hering, Benjamin Lorenz, Benjamin Nill, Andreas Paffenholz, Francisco Santos, and Hal Schenck. Few smooth d-polytopes with N lattice points. arXiv:1010.3887.

[BK] Tristram Bogart and Eric Katz. Obstructions to lifting tropical curves in hypersurfaces. arXiv:1101.0297.

[Zie95] G.M. Ziegler. *Lectures on Polytopes*, volume 152 of *Graduate Texts in Mathematics*. Springer-Verlag, New York, 1995.

To Whom It May Concern:

During the academic year 2010-2011, Tristram Bogart held an NSF / MSRI Postdoctoral Fellowship at San Francisco State University, where I served as his postdoctoral adviser. The department benefitted greatly from Tristram's active presence, and I believe that Tristram also found it to be quite a productive time.

In terms of research, Tristram was involved in several different projects. He wrapped up a very nice project with Eric Katz on obstructions to tropical lifting, as well as a catalog of small smooth polytopes with a large group of experts in the field. He also began several new projects, the main two being collaborations with SFSU Prof. Joseph Gubeladze, and with myself.

With Joseph Gubeladze, he studied the “mapping polytope” of all affine linear maps from one polytope into another one. This is a key (and poorly understood) construction in the development of a category of polytopes. Tristram and Joseph were able to prove structural results and compute concrete examples, which make explicit several ways in which these are difficult objects to work with.

Tristram and I studied a construction of “new polytopes from old”, which I encountered in the theory of weighted Ehrhart polynomials. We were able to show that, given a normal polytope P in d-space, this construction leads to an infinite family of normal polytopes, one for each d-tuple of positive integers. There are several conjectures about normal polytopes, and one difficulty is the lack of examples of such polytopes. We hope that this large new family of examples will help us settle some of these conjectures.

Tristram also had his first chance to help guide the research of Master's and undergraduate students. He had numerous valuable discussions with Matt Beck's SFSU student Tu Pham, Joseph Gubeladze's SFSU student Jimmy McErlain, and my Los Andes (Colombia) undergraduate student Jose Samper. More informally, he was also very actively involved in the day-to-day life of the department and injected great enthusiasm to our students.

While at SFSU, Tristram also had a chance to gain experience in some service activities in the profession. He helped Matt Beck and I organize some logistical aspects of FPSAC 2010, the annual international conference in algebraic combinatorics. With our help, he also led the organization of BADMath Day, the biannual meeting of combinatorialists in the Bay Area. This gave him very valuable organizational experience, as well as substantial visibility in the field.

I am thrilled that Tristram has accepted a tenure-track position at the Universidad de Los Andes in Bogota, arguably Colombia's top math department. He was hired at the same time as algebraic geometer Jarod Alper (a former student of Ravi Vakil) and commutative algebraist Mauricio Velasco (a former student of Mike Stillman), and I am very eager to see the results of their future collaboration. I am also selfishly pleased, since I hold an Adjunct Professorship at Los Andes, and am looking forward to continuing to collaborate with Tristram. We have already arranged to advise our first joint undergraduate thesis student.

All in all, we are very thankful to the NSF and the MSRI for the opportunity that we had to host Tristram Bogart at SFSU. Although we are a department with a very active research agenda, our funding situation makes it almost impossible to fund postdoctoral researchers. I believe this arrangement was extremely fruitful for Tristram and for our department.

Federico Ardila

MSRI FELLOWSHIP FINAL REPORT

SCOTT CROFTS

Name: Scott Crofts
Year of Ph.D: 2009
Institution of Ph.D.: University of Utah (prior institution)
Ph.D. advisor: Peter Trapa

Institution where you held your MSRI PD fellowship: University of California, Santa Cruz
Mentor at that institution: Martin Weissman

Institution (or company) where you are going next year: TBD

This is the conclusion to a very productive year for me with MSRI and UCSC. My biggest accomplishment for the year was the acceptance and publication of my first paper. The title is "Vogan Duality for Nonlinear Type B" and it appears in the most recent issue of the electronic journal 'Representation Theory'. This paper represents a significant generalization of the results of my thesis and was under review for more than 16 months (its long - approximately 50 pages cut down from 75). Roughly speaking, it is an extension of a deep result in the representation theory of real linear Lie groups to certain nonlinear 'Spin' groups of type B. For technical reasons, the paper focuses only on the even rank case, but I have made progress on the odd rank case as well and hope to return to that in a future paper.

In the fall of 2010 I was fortunate enough to teach a course at UCSC. It was a 'calculus with applications' course for biological sciences majors. There were about 300 students enrolled and I was responsible for supervising 4 TAs, 5 graders, 8 discussion sections, and 1 (very large) lecture. Although it was a lower division course, it was still a great experience. Certainly it was the largest class I have ever taught, and dealing with that number of students, TAs, and graders is definitely a challenging management problem. Overall I learned a great deal about teaching from this experience and feel pretty confident that I can handle just about any teaching assignment in the future.

I have two ongoing collaborations that I continued to pursue this year. My first one is with Jeffrey Adams at the University of Maryland. I spent the first week of May this year visiting Jeff in Baltimore. Jeff is a PI for the 'Atlas of Lie Groups and Representations' project (www.liegroups.org). We are working to develop mathematics and algorithms for making representation theoretic calculations on a computer. Our primary focus is on nonlinear simply-laced double covers of real Lie groups. Although we have a preprint of what will likely be our first paper together, we are working to reformulate our results in a way that will make them interesting to a wider audience. My hope is that we will submit a paper sometime this summer.

My second collaboration is with my Ph.D. advisor Peter Trapa. Peter and I are attempting to classify and describe the W-cells of genuine representations for nonalgebraic real groups of type A. Although we are supremely confident that we have the correct answer, we have hit a few difficulties in proving it. I hope to visit Peter sometime this summer and resolve these issues.

On a personal note, I would just like to say that I enjoyed my experience with MSRI and UCSC very much and I am extremely grateful for all the support. I almost certainly would not have been able to continue with any of these projects, or have these experiences, had it not been for this program and I would like to thank everyone involved.

As his mentor at UCSC, I had frequent contact with Scott, and often discussed his outstanding research. I've enjoyed having him around!

Scott works in a technical, fascinating, and (in the long term) vitally important corner of representation theory. Specifically he works on certain "double-covers" of linear real reductive groups. These groups have been around for many decades, but they've never quite fit into the general "parameterization" program of Langlands, Arthur, and Vogan. Many leading researchers avoid these double-covers entirely, but this has left significant gaps in our understanding.

Scott has succeeded in two ways. First, he has filled in some of these gaps in our understanding of double covers, and his significant thesis work is now accepted for publication. Secondly, his work is not only theoretical, but realistically computable. Working with the ATLAS project, Scott has adapted Vogan's geometric parameterization (pairs of K-orbits on the flag variety of a group and its dual) to some double covers, in order to describe a parameterization of representations that a computer can carry out. This ability to combine proof and algorithm is rare, and Scott has excelled.

Scott was not only an active researcher during his time at UCSC, but he was also actively involved in the department. He spoke in our algebra seminar, as well as the undergraduate math colloquium. He taught two courses, and as the undergraduate vice-chair, I'm aware that he did an excellent job. I'm not sure what the future holds for Scott, but I certainly hope that his successful research is appreciated and can continue.

Please feel free to drop a note if you have further questions. It's been a pleasure working with Scott!

Marty Weissman
Assistant Professor
Undergraduate Vice-Chair
Dept. of Mathematics
UC Santa Cruz

Final report

for MSRI funded postdoc at Stanford, 2010-11.
Anton Dochtermann

My MSRI funded postdoc ran from August 1, 2010 through May 31, 2011. I was given office space at Stanford University where my postdoctoral mentor was Professor Gunnar Carlsson. In addition, I spent some scheduled time at UC Berkeley meeting with colleagues and participating in seminars there. Included here is a brief description of some of my mathematical activities during this time.

- Seminars

  In addition to attending several local regular seminars during the academic year (UC Berkeley combinatorics, Stanford topology, Stanford algebraic geometry, UC Berkeley commutative algebra, etc.), I also helped organize the following.

  - Topological combinatorics at UCB

    In Fall 2010 and Spring 2011 I co-organized a reading seminar on Topological Combinatorics at UC Berkeley with Alex Engström. The topic for the Fall quarter was *Moment angle complexes and generalized Davis-Januskiewicz spaces* and the topic for Spring was *Matroid bundles and combinatorial classifying spaces*, and we also had a handful of visitors give talks on related topics. A link for the seminar can be found here

    `http://math.stanford.edu/ anton/seminar2011.html`

    The seminar was well attended (about 8 consistent participants, along with other 'drop-ins') and was a good learning opportunity for those involved, leading to potential future projects.

  - Computational topology at Stanford

    In the Fall 2010, Winter 2011, and Spring 2011 seminars I participated in the weekly computational topology reading seminar at Stanford. This mostly involved participants presenting research papers relevant to the interests of the group, with some discussion following. The seminar was comprised of grad students, a few postdocs (including myself), and a faculty member. It was good opportunity for me to familiarize myself with the current research in the area.

- Conferences and talks

  Over the course of the last year, I presented my own research at a number of local and (inter)national seminars and conferences. In most case travel funding from the MSRI made it possible to attend the meetings that were held outside of the bay area. The included the following.

  - UC Berkeley Discrete Math Seminar
  - U Washington Combinatorics Seminar
  - U Miami Combinatorics Seminar

- UC Davis Combinatorics Seminar
- Stanford Computational Topology Seminar
- Bay Area Discrete (BAD) Math day, SF State University
- Canadian Math Society 2010 Winter Meeting (Special Session on Commutative Algebra and Combinatorics)

In addition, I was fortunate to be able to attend a number of local conferences. This summer I will participate in the *Computational and Applied Topology* AMS Math Research Community in Snowbird. I will also use MSRI travel funds to attend an Applied Topology conference in Zurich, as well as the *MONICA* conference on Monomial Ideals being held in Cantabria, Spain.

- Other Projects

  With Gunnar Carlsson, Henry Adams, Daniel Müllner, and Mikael Vejdemo-Johansson I have started a project working out a mathematical theory of *evasion*. The project grew out of a particular question in an applied setting, namely how to determine if an 'evading' body can avoid detection from a collection of moving sensors in some domain. The setup leads to some new and exciting mathematical, and I look forward to continuing this collaborative work.

  I have also become involved in a project with Caroline Uhler, a graduate student at UC Berkeley. In her work with modeling chromosomes in protein, she came across the need for certain tools in computational topology. Once again, these considerations lead to the need for new methods and applications.

- Publications

  Although no publications have appeared during my time as an MSRI funded postdoc, I have been revising, submitting, and preparing the following papers.

  - *Coarse tropical type decompositions and associated cellular resolutions*, with Michael Joswig and Raman Sanyal, 28 pages.
  - *Face rings of cycles, associahedra, and standard tableau*, 15 pages.
  - *Cellular resolutions via mapping cones*, with Fatemeh Mohammadi, 12 pages.
  - *Relating topological and probabilistic bounds on chromatic number*, work in progress.

  In addition, I served as referee for a papers submitted to the Journal of Algebraic Combinatorics and the Journal of Combinatorial Theory, Series A.

-------- Original Message --------
Subject: Anton
Date: Fri, 03 Jun 2011 09:55:00 -0700
From: Gunnar Carlsson <gunnar@math.stanford.edu>
To: hbarcelo@msri.org

Hi Helene,

I understand you need a report on how the postdoctoral fellowship for Anton Dochtermann at Stanford has gone. I believe it has been an intellectually useful time for Anton. He has worked on a number of things, including graph homomorphisms, monomial resolutions, and more recently he has been getting involved in our project on computational and applied topology. He has initiated seminars in some of these areas, and he has been a valuable part of the research effort here. I hope to continue to work with him on the computational project mentioned above, and I also feel that his work on monomial resolutions may ultimately have an impact in that area as well as in equivariant questions.

I hope this is what you need - if you need more, don't hesitate to write.

Best,

Gunnar Carlsson

Christopher Hillar Grant Report
2010-2011 Academic Year

Christopher J. Hillar
University of California, Berkeley, 2005, Ph.D.
Ph.D. advisor: Bernd Sturmfels

Institution prior to obtaining the MSRI PD fellowship: Texas A&M University
Visiting Assistant Professor and NSF Postdoctoral Fellow
Postdoc Advisor: Frank Sottile

Institution where you held your MSRI PD fellowship: University of California, Berkeley
Mentor: Friedrich Sommer (Redwood Center for Theoretical Neuroscience)

Institution (or company) where you are going next year:
Redwood Center for Theoretical Neuroscience
University of California, Berkeley
Position: Postdoc
Anticipated length: 1 Year

My work falls into two sections: (1) Pure Mathematics and (2) Theoretical Neuroscience. As I am transitioning fields, it is important to honor my obligations to collaborators (both old and new), so I have tried to be as diligent as possible in pushing out old projects and folding in new ones.

(1) Pure Mathematics

With Seth Sullivant, we have proved the Independent Set Conjecture in Algebraic Statistics. The proof involved unifying and generalizing several ideas concerning polynomial rings with infinite numbers of variables. We also introduced the notion of monoidal Groebner Bases, which are useful tools for proving finiteness of invariant ideals in semigroup rings that have a monoidal action. The work has recently been accepted:

C. Hillar and S. Sullivant, Finite Groebner bases in infinite dimensional polynomial rings and applications, Advances in Mathematics, to appear.
http://arxiv.org/abs/0908.1777

Related to this work is a paper in preparation with Abraham Martin del Campo on invariant chains of toric ideals:

C. Hillar and A. Martin del Campo, Symmetric stabilization of toric ideals, in preparation.
www.msri.org/people/members/chillar/files/HM-InvarChainStabDec10.pdf

With Lek-heng Lim, we have proved that most tensor problems are NP-hard (tensors are the natural generalization of matrices to higher dimensions). We are preparing the article for publication, but a preliminary manuscript is here:

C. Hillar and L.H. Lim, Most tensor problems are NP-Hard, preprint
http://www.msri.org/people/members/chillar/files/tensorNPhardApril8.pdf

With Corey Irving, we are preparing a submission to the Notes section of the American Mathematical Monthly. It involves an area optimization resulting in the barycenter as unique optimal solution. A preliminary manuscript can be found here:

C. Hillar and C. Irving, A triangle area inequality optimized by the barycenter, preprint
http://www.msri.org/people/members/chillar/files/triangle_area_inequality.pdf

With Lionel Levine and Darren Rhea, we have submitted the following work.

C. Hillar, L. Levine, and D. Rhea, Equations solvable by radicals in a uniquely divisible group, submitted.
http://www.msri.org/people/members/chillar/files/HLR-UniDivGrps.pdf

It involves the construction of a uniquely divisible group with certain word equation solving properties. The proof incorporates a new polynomial in two (commuting) variables, called the word polynomial, whose properties characterize which word equations in two (noncommuting) variables have solutions "in terms of radicals". I have given the following talks on this work:

Word equations in a uniquely divisible group
April 27, 2010, Microsoft Theory Seminar, Seattle, WA.

Word equations in a uniquely divisible group
March 8, 2010, U.C. Berkeley Discrete Mathematics seminar, Berkeley, CA.

With Jesus de Loera's computational algebra group at U.C. Davis we have completed the following project some Groebner basis techniques for solving certain hard combinatorial problems:

J. De Loera, C. Hillar, P. Malkin, M. Omar, Recognizing Graph Theoretic Properties with Polynomial Ideals, Electronic Journal of Combinatorics, to appear.
http://arxiv.org/abs/1002.4435

(2) Theoretical Neuroscience

I have two main projects in the nascent field of mathematical neuroscience. The most complete project is a theory of brain communication through axonal fiber bottlenecks. This is work in collaboration with Friedrich Sommer of the Redwood Center for Theoretical Neuroscience at U.C. Berkeley (my fellowship research mentor) and a young Berkeley Neuroscience graduate student Guy Isely. The ideas are outlined in the paper (which was an invited spotlight talk at the NIPS 2010 Conference):

G. Isely, C. Hillar, and F. Sommer, Decyphering subsampled data: Adaptive compressive sampling as a principle of brain communication. Advances in Neural Information Processing Systems 23. Eds: J. Lafferty and C. K. I. Williams and J. Shawe-Taylor and R.S. Zemel and A. Culotta (2011) 910-918.

With my research mentor, we have also worked out the mathematics of the theory and submitted it to a research journal:

C. Hillar and F. Sommer, Ramsey theory reveals the conditions when sparse coding on subsampled data is unique, preprint.
http://arxiv.org/abs/1106.3616

Surprisingly, our arguments required the incorporation of some basic results in combinatorial Ramsey Theory. I have given a number of talks on the subject, including:

Ramsey theory reveals the conditions when sparse coding on subsampled data is unique
May 31, 2011, U. Chicago Statistics Seminar, Chicago, IL.

Communication in the brain
Feb. 3, 2010, U.C. Berkeley Mathematical & Computational Biology Seminar, Berkeley, CA.

Applications of Ramsey theory to neuroscience
Dec. 15, 2010, UC Berkeley Student Seminar in Discrete Mathematics, Berkeley, CA.

Adaptive compressed sensing - a new class of self-organizing coding models for neuroscience
March 17, 2010, IEEE 2010 International Conference on Acoustics, Speech, and Signal Processing, Dallas, TX.

Adaptive compressed sensing - a new class of self-organizing coding models for neuroscience
October 13, 2009, Agent-Based Complex Systems, IPAM (Institute for Pure and Applied Mathematics), Los Angeles, CA.

The other main research line I maintain in mathematical neuroscience is a mathematical model of neuronal sensor networks with Kilian Koepsell. I gave the following invited talk about this work:

Neural Networks Computing Relaxations of Hard Combinatorial Problems
May 22, 2011, SIAM 2011 Conference on Dynamical Systems, Snowbird, UT.

I also have a paper related to this work in preparation:

C. Hillar, J. Sohl-Dickstein, K. Koepsell, Unsupervised binary pattern storage from noisy samples using minimum probability flow, in preparation.

When applied specifically to the retina, our models might be useful for retinal prosthesis.

I also gave an accepted submission talk about my work with Kilian Koepsell on sensor models and their relationship to eigenvector computations in numerical linear algebra at the Householder conference:

Spectral Relaxations of Hard Combinatorial Problems
June 14, 2011, Householder Symposium XVIII, Tahoe City, CA.

REDWOOD CENTER
for Theoretical Neuroscience

Redwood Center for Theoretical Neuroscience
University of California, Berkeley
156 Stanley Hall, MC #3220
Berkeley, CA 94720-3220, USA

July 1st, 2011

Postdoc Report for:
Dr. Christopher Jacques Hillar
NSA Postdoctoral Fellow
Mathematical Sciences Research Institute
Berkeley, CA 94720

Chris Hillar and I collaborated on a project with the goal to combine compressed sensing and dictionary learning. Chris was able to prove that dictionary learning on compressed data, when converged, is able to reveal a dictionary for the compressed data and recover the sparse causes of the original (uncompressed) data. This statement holds if the recovery conditions for compressed sensing are fulfilled. This theorem is important for technical applications and for neuronscience, in particular, the question how brain areas can communicate through smaller subsets of neurons that send axonal fibers between brain areas. These results are described in a NIPS 2011 paper and in submitted journal manuscript.

In addition, Chris is involved in various projects with other members of the Redwood Neuroscience Institute. Further, Chris advised students at the Redwood Center and has given many excellent talks about mathematical issues with topics of Theoretical Neuroscience. In the last two years Chris was able to add to his expertise a solid body of experience and knowledge in the field of Theoretical Neuroscience.

Sincerely yours,

Friedrich Sommer

Friedrich T. Sommer, Ph.D.
Associate Adjunct Professor & Acting Director
Redwood Center for Theoretical Neuroscience
University of California Berkeley

NSF REPORT FOR ERIC KATZ

Ph.D. 2004, Stanford University
Advisors: Ravi Vakil and Yakov Eliashberg

Institution prior to obtaining the MSRI PD fellowship: University of Texas-Austin
Position at that institution: Lecturer-RTG Postdoc
Mentor: Sean Keel

Institution where you held your MSRI PD fellowship: University of Texas-Austin
Mentor at that institution: Sean Keel

Institution where you are going next year: University of Waterloo
Position: Assistant Professor
Anticipated length: tenure-track

In the past year, I have been involved in a number of projects in tropical geometry, an area of algebraic geometry that involves transforming questions about algebraic varieties into questions about polyhedral complexes. Tropicalization is a method that associates to a subvariety X of an algebraic torus $(\mathbb{K}^*)^n$ (where $\mathbb{K}$ is a discretely valued field), a weighted polyhedral complex, $\mathrm{Trop}(X)$. Such complexes are called tropical varieties. The tropical varieties capture a number of properties of the original variety. My research is in a broad sense devoted to two ideas: how algebraic geometric properties are reflected in tropical geometry; and how to characterize tropical varieties among polyhedral complexes. In this direction, I have written a number of papers or preprints in the last year and begun a couple of projects.

In a recent paper with Alan Stapledon, a former postdoc at University of British Columbia, "Tropical Geometry and the Motivic Nearby Fiber," I introduced a new invariant, the tropical motivic nearby fiber. It is a motivic invariant of an algebraic subvariety of a toric variety defined over a valued field. In the schön case, it specializes to the Hodge-Deligne polynomial of the limit mixed Hodge structure of a corresponding degeneration. It can be used to give purely combinatorial expressions for the Hodge-Deligne polynomial in the cases of schon hypersurfaces and smooth tropical varieties. It gives a formula for the Euler characteristic of a general fiber of the degeneration. The paper has been accepted for publication in *Compositio Mathematica*. Stapledon and I have planned a sequel that will focus on hypersurfaces and give some applications to Erhart theory.

I have addressed questions of which tropical curves in space come from classical curves in space in a paper, "Lifting Tropical Curves in Space and Linear Systems on Graphs" which is pending revisions for *Advances in Mathematics*. This work was studied by David Speyer in the genus 1 and Takeo Nishinou in higher genus but of particular combinatorial type. They have found a necessary and sufficient condition in their cases. I have discovered a necessary condition in higher genus which is more general than Nishinou's. My condition is phrased in the language of linear systems on graphs developed by Matt Baker. It implies Nishinou's condition in the cases where it applies and gives new ones in other cases. This is part of what I hope will be a project towards understanding obstruction theory combinatorially.

In a submitted paper with Tristram Bogart, an MSRI postdoc at San Francisco State University, "Obstructions to Lifting Tropical Curves in Hypersurfaces," I address the question of which graphs in a tropical surface in 3-space, come from an algebraic curve in the corresponding hypersurface. I develop specific combinatorial obstructions to a graph lifting by studying the factorizations of polynomials with particular support. This gives an understanding of some pathological tropical curves constructed by Vigeland and also give examples to show which lifting questions are purely combinatorial.

I have a project studying the realization spaces of tropical varieties. Given a weighted rational polyhedral complex, Σ in $\mathbb{R}^n$, one may ask which subschemes $X \subset (\mathbb{K}^*)^n$ have $\mathrm{Trop}(X) = \Sigma$. I construct the space of all such schemes as an admissible open sets in the analytification of an appropriate Hilbert scheme. This allows me to employ rigid analytic techniques to study them. In particular, I show that if a polyhedral complex is the tropicalization of a formal family of varieties then it is the tropicalization of an analytic family of varieties. These results are in my preprint, "Tropical Realization Spaces and Tropical Approximations."

I have a submitted paper, "Log-concavity of the characteristic polynomial and the Bergman fan of matroids," joint with June Huh. This project is to understand the log-concavity of the coefficients of the characteristic polynomial of a matroid. Establishing log-concavity is a long-running conjecture in combinatorics. A breakthrough was recently obtained by June Huh, a graduate student at University of Illinois who was able to prove the conjecture for matroids realizable over a field of characteristic 0. By rephrasing Huh's work in terms of intersection theory in toric varieties, we were able to simplify his arguments and extend his result to any matroid realizable over any field. I hope to investigate the general conjecture in the future.

Another strand of my research involves monodromy and tropical varieties which I study in a paper with David Helm, a faculty member at University of Texas, "Monodromy Filtrations and the Topology of Tropical Varieties." This paper has been accepted for publication in *Canadian Journal of Mathematics.*

I have begun a long-term project to understand a tropical version of Schubert calculus. This project is joint with Maria Angelica Cueto, a postdoc at Mittag-Leffler and Columbia University and Leonardo Mihalcea, a faculty member at Baylor University. Our approach is to come up with an analog of the tropicalization procedure which is equivariant under the action of a linear algebraic group. We made significant progress towards defining Gröbner fans and tropical varieties as combinatorial objects in the Bruhat-Tits building associated to the group.

In fall 2010, I taught linear algebra for math majors on a volunteer basis for the University of Texas.

-------- Original Message --------
Subject: Report on Erik Katz's Post Doc at UT
Date: Wed, 29 Jun 2011 11:27:34 -0500 (CDT)
From: keel@math.utexas.edu
To: hbarcelo@msri.org

To whom this may concern.

This is a report on Erik Katz's final year as a post doc at UT. To be honest I do not have much first hand knowledge of Katz's activities: Unlike my previous two postdocs (Eugene Tevelev and Ana-Maria Castravette) with whom I worked very closely, Katz's mathematical inclinations diverged from mine, and he did not consult with me in any meaningful way -- this is a remark absolutely devoid of judgement, just a statement of fact. I know, from a talks he gave, that he did some reasonable work on the so called tropical near by fibre, and on the natural question of which tropical varieties are tropicalisations of actual varieties. On the strength of his results, he got a tenure track job in Canada at a school (Waterloo) with a good research tradition.

Sincerely,
Sean Keel
Prof. of Mathematics
Univ. of Texas at Austin

Year-End Report 2010–11
NSF Math Institutes Postdoctoral Fellowship

Karl Mahlburg

1 Summary

I began my second year as an NSF Math Institute Postdoctoral Fellowship with two major goals: 1) Apply for and obtain a permanent position at a research-oriented institution; 2) Complete writing up the results of several completed research projects and submit the articles for publication in high-level journals. I was successful in achieving both goals, as during the past year I submitted three new research articles for publication, and was also hired as a tenure-track Assistant Professor at Louisiana State University. I continue to be very thankful for the NSF's support of my postdoctoral Fellowship during the past two years, which has allowed me to focus on establishing a long-term career as a research mathematician.

One of the primary reasons behind the funding of the NSF Math Institute Postdoctoral Fellowships was to help promote future career opportunities for young mathematicians affected by budget difficulties at universities. I devoted a significant amount of time and effort in my final postdoctoral year to first applying for permanent positions and research grants, and then traveling to interviews and conferences in order to pursue as many professional opportunities as possible. The flexibility of my NSF Fellowship was very helpful in all of my travels, and I was pleased to receive offers of employment at two research institutions.

After I had successfully secured permanent future employment, I also continued to develop my existing research program, and also explored new directions and collaborations. The latter was significantly helped by my residence at MSRI during the spring semester for the Arithmetic Statistics program, where I learned a great deal about current developments in the algebraic theory of elliptic curves, as well as computational approaches to automorphic forms. My general research program has expanded to include the general theory of automorphic properties of q-series, which intersects with a wide variety of mathematical topics, including mathematical physics, the combinatorics of integer partitions, probability and percolation theory, characters of affine Lie algebras and superalgebras, and the arithmetic properties of class numbers. In particular, the connections between number theory and many of these topics have only recently been understood thanks to developments in the theory of mock modular forms and Jacobi forms. As I begin my new position, I expect to complete research articles on all of these topics and more, and I am confident that the research that I have begun as an NSF Math Institute postdoc will continue to lead to new results during the coming years.

2 Professional Travel

Oct. 17 - 20, 2010 **Number Theory Seminar**, Yale University. Presented talk "Percolation, Partitions, and Probability". Worked with A. Folsom on "A new continued fraction for a mock theta function".

Dec. 2 – 28, 2010 **University Visit,** University of Talca. Presented Colloquium talk "Noncrossing partitions and general Catalan objects". **Workshop on the Arithmetic of Quadratic Forms and Integral Lattices**, Futrono, Chile. Presented talk "Asymptotics for mock theta functions and probability sequences". **First International Meeting of the American Mathematical Society and the Sociedad de Matematica de Chile**, Universidad de la Frontera, Pucón, Chile. Presented talk "Mock modular forms and coefficient asymptotics for characters of affine Lie superalgebras".

Jan. 3 – 8, 2011 **Recruitment Visit**, Ohio State University. Interviewed with faculty and Dean, and presented seminar "Percolation, Partitions, and Probability".

Jan. 5 – 8, 2011 **AMS/MAA Joint Meetings**, New Orleans. Attended Conference Sessions and interviewed at Employment Center.

Jan. 10 – 17, 2011 **Research Visit**, University of Cologne, Germany. Worked with K. Bringmann on "Overpartitions with k-runs and probability".

Jan. 21 – 24, 2011 **The Number Theory of Partitions Conference**, Emory University. Presented talk "Asymptotics for the coefficients of Kac-Wakimoto characters".

Jan. 25 – 28, 2011 **Recruitment Visit**, University of Missouri-Columbia. Interviewed with faculty and Dean, and presented seminar "Mock theta functions, partitions, probability, and percolation".

Feb. 1 – 3, 2011 **Recruitment Visit**, Louisiana State University. Interviewed with faculty and Dean, and presented seminar "Percolation, partitions, and probability".

Feb. 6 – 11, 2011 **Recruitment Visit**, University of Sydney, Australia. Interviewed with faculty and Dean, and presented seminar "Percolation, partitions, and probability".

Mar. 13 – 20, 2011 **School and Conference on Modular Forms and Mock Modular Forms and their Applications in Arithmetic, Geometry and Physics**, Abdus Salam International Center for Theoretical Physics, Trieste, Italy. Presented talk "Mock Jacobi forms and moment asymptotics".

Apr. 20 – 22, 2011 **Colloquium**, Wesleyan University. Presented talk "Percolation, probability, and partitions".

May 1 – 3, 2011 **Colloquium**, University of North Texas. Presented talk "Percolation, probability, and partitions".

3 Research activity

Articles completed and submitted:

- (with K. Bringmann and R. Rhoades) *Asymptotic expansions for rank and crank moments.*
- (with K. Bringmann and A. Mellit) *Convolution bootstrap percolation models, Markov-type processes, and mock theta functions.*
- (with K. Bringmann) *Coefficient formulas for traces of affine Lie superalgebras.*

Articles in preparation:

- (with A. Holroyd and L. Levine) *Dimensional reduction and unexpected symmetries in abelian sandpiles.*
- (with A. Folsom) *A new continued fraction for a mock theta function.*

- (with C. Smyth) *Symmetric polynomials and quasi-mean inequalities.*
- (with K. Bringmann and A. Holroyd) *Probability sequences, q-series, and overpartitions*, preprint.

MSRI POSTDOCTORAL FELLOWSHIP REPORT FOR KARL MAHLBURG

Manjul Bhargava

Karl has been doing some very impressive work this past year. His work has focused primarily on applications of automorphic forms (particularly mock modular forms) and q-series to number theory. In this regard, he has done some fantastic work with Kathryn Bringmann, and spent much of the past year visiting her in Cologne, Germany. This has led to his already very well-received paper on asymptotic expansions for crank and rank moments. This work has taken him into some serious probability and percolation theory, as evidenced in his soon-to-appear papers with Bringmann and Mellit and then with Bringmann and Holroyd. I believe that these remarkable connections which these authors have discovered will play an important role in much work to come by these and other authors.

Karl has also kept up his strong interest in combinatorics, particularly his work relating to tilings, sandpiles, and symmetric polynomials. He has continued to do very interesting work on these problems as well.

Finally, Karl has spent a lot of time this year giving lectures all over the world, both because of the recent interest in his work, and also to secure a permanent position somewhere (with which he has succeeded). He also spent much time visiting his collaborators Bringmann at Cologne, and Folsom at Yale. The latter visit has resulted in a new work on continued fraction expansions for mock theta functions.

With best regards,

Manjul Bhargava

Name: Sikimeti Mau
Year of Ph.D.: 2008
Institution of Ph.D.: Rutgers, The State University of New Jersey
Ph.D. advisor: Christopher Woodward
Institution prior to obtaining MSRI PD fellowship: MSRI
Position at that institution: 1 year Special Program postdoc
Institution where you held your MSRI PD fellowship: Barnard College
Mentor at that institution: Dusa McDuff
Institution (or company) where you are going next year: UC Berkeley
Position: Postdoctoral fellowship
Anticipated length: 3 years **Mentor:** Denis Auroux
Report.
Mentor meetings: In the Fall semester I had meetings approximately every week with my mentor, either via Skype or in person. That semester I was also on the job market, putting together job applications as well as NSF grant applications, and she provided a lot of valuable feedback on the various statements that I was writing, about the actual research content as well as editorial comments. During the Spring semester we didn't manage to meet quite so religiously, mostly due to a lot of scheduled travel, and since I was in Berkeley I met more often with Denis Auroux, who will be my mentor at UC Berkeley (my job following this fellowship).
Travel and talks: During the year I was invited to a number of seminars and conferences. In the Fall I gave talks at Columbia University's geometry seminar the University of Texas at Austin's geometry seminar. In the Spring I gave a talk at the UC Berkeley topology seminar. In the Spring semester I traveled to a Low Dimensional Topology conference in Banff, Canada, an Equivariant Quantum Cohomology workshop at the Simons Center in Stony Brook, NY, and the Georgia Topology Conference in Athens, GA. The fellowship provided a generous amount of travel funding, which allowed me to plan to attend workshops and conferences without having those plans be contingent on funding. Being able to travel in these early stages of my professional career has probably been quite influential in developing a professional profile. Over the summer I have been invited to speak at workshops in France and Germany.
Teaching: In the Fall I did a small amount of teaching at Barnard College. I taught three weeks' worth of an undergraduate course “Introduction to Higher Mathematics”, a course for potential math majors about rigorous proofs.
I also taught a three week unit of a general interest course called “Perspectives in Mathematics”, introducing the notion of conformal maps and their connections to complex numbers. The class consisted of undergraduates who for the most part were not math majors, but interested in learning math that wasn't calculus.
Papers worked on Fall 2010 - Spring 2011:
"Quilted Strips, graph associahedra and A-infinity n-modules" (submitted)
"Quilted Floer A-infinity modules" (in preparation, grew out of a manuscript originally intended to be "A note on Bimodules and Lagrangian correspondences")
"A-infinity functors for Lagrangian correspondences" (in preparation, joint with C. Woodward and K. Wehrheim)

Final report: mentoring Sikimeti Ma'u

Our most significant interactions took place in the Fall. I first tried to make sure that Sikimeti was progressing in her research, and then in her job search. Initially this search was very frustrating, and I think our contact was useful in helping her keep a positive attitude. Upon my advice, she rewrote her research statement several times, both to make it more readable and to explain her own contributions to the subjects more clearly.

She visited Barnard and Columbia several times in the Fall; I discussed teaching and research issues with her then. Her teaching with its careful explanations was much appreciated. I also arranged for her to give a talk in the Columbia seminar. She used these trips very sensibly, also scheduling visits to her collaborators in Rutgers and at MIT.

I encouraged her to talk to Auroux in Berkeley, since his research interests are much closer to hers than mine are. By the Spring she had developed a very good interaction with him. Specially after she had obtained a job in Berkeley with him as mentor, there was not such a pressing need for us to be in contact. However, we did remain in touch, and I recently met her in person at the Simons Center in Stony Brook. We talked about her progress with writing papers and her research plans.

This has been a very fruitful year for Sikimeti. She has developed very nicely and has excellent prospects for the future.

Dusa McDuff
Kimmel Professor of Mathematics at Barnard.
June 14, 2011

Your Name**: Abraham David Smith**

Year of Ph.D: 2009

Institution of Ph.D.: Duke University, Department of Mathematics

Ph.D. advisor: Robert L. Bryant

Institution where you held your MSRI PD fellowship: McGill University, Department of Mathematics and Statistics

Mentor at that institution: Niky Kamran

Institution (or company) where you are going next year: Fordham University, Mathematics Department

Position: Visiting Assistant Professor

Anticipated lenght: (if it is a tenure track position just write tenure-track) 4 years

My annual report is here:

This is my report of academic activities as an MSRI NSF All-Institutes postdoctoral fellow for the 2010-11 academic year under the mentorship of Niky Kamran at McGill University.

I received positive referee reports on my paper “Integrable GL(2) Geometry and Hydrodynamic Partial Differential Equations” arXiv:0912.2789 during the summer of 2010, and the final version of that paper was accepted by Communications in Analysis and Geometry and published in the October 2010 volume.

My research since the Spring of 2010 has been focused on a geometric study of hyperbolic partial differential equations [PDEs] in N>2 independent variables and one dependent variable. This began as an extension of the paper listed above, but it is now more accurate to say that the paper above covers a peculiar sub-case of this larger program. This research program has split into two parts: First, I sought an intrinsic (coordinate-free) classification of second-order PDEs using techniques from conformal differential geometry and moving frames. This involved the development of a new geometric structure and the corresponding invariant theory. I finished an early preprint [arXiv:1010.6010] in October 2010 that covers this material. Second, I am continuing to try to understand the geometric criteria on these PDE structures that correspond to “hydrodynamic integrability”, a popular notion of integrability arising from the analysis of semi-Hamiltonian (a.k.a. "rich") systems of conservation laws. I hope that the geometric approach will clarify which aspects of the analysis are contact invariant (independent of the coordinate description of the PDE) and which are not. If luck prevails, it will provide a complete list of all such integrable PDEs in the physically interesting case of N=4 (space+time).

While developing the second part of this research program, there have been several unexpected technical hurdles that have slowed me from my original 1-year timeline for this program, now in its 15th month. However, I expect to have a preprint on the "Part 2" material before the beginning of the Fall semester, and a combined article will be submitted for publication shortly thereafter.

I have given talks on this work at the “Differential Geometry and its Applications” conference talk in Brno, CZ in September 2010, at Texas A&M University in October 2010, and at a special workshop on conformal geometry at the University of Arkansas in April 2011. I also made trips to Texas A&M University in November 2010 and the University of Colorado in December 2010 to collaborate and discuss research with Dennis The, Jeanne Clelland, George Wilkens, and Matt Stackpole.

In addition to this 2-part program, I have hypotheses for another project that arose while considering various aspects of the original problem, and I expect to actively pursue it in the Fall 2011 semester.

Aside from my own research, there have been several other academic activities. I refereed a paper for a highly-regarded journal in Fall 2010. I have tried to be of service to Niky Kamran's current graduate students, including serving on the exam committee of one of the PhD candidates and giving some suggestions on how to approach a new problem for another PhD candidate. Finally, Francis Valiquette, Niky Kamran, and I have organized the workshop "Moving Frames in Geometry" at CRM in Montreal in June 2011.

Dr. Helene Barcelo
Mathemaical Sciences Research Institute

May 25, 2011

Dear Helene,

Abraham Smith is about to complete his second and final year as as MSRI NSF Postodoctoral Fellow at McGill.

The main focus of Abe's research during this year has been to develop a comprehensive geometric framework for studying hydrodynamic reductions and integrabilty for second order partial differential equations in four variables or more. This is one of the most important sets of open questions in the geometrical study of differential equations, and it is closely related to the issue of integrability in more than two independent variables, widely considered as the most important open problem in the field.

Abe has made a great deal of progress on this question, which is technically very challenging. He has a general structure theorem and the beginnings of a classification theorem, with local normal forms, practically completed. This will lead to a paper which will become a classic in the field. (The general structure theorem has already been written up and posted on the arXiv.)

Throughout the year, Abe has been a very active participant in the geometry seminar and a wonderful mentor to the post-docs and graduate students in the Department. He is also co-organizing with Francis Valquette a workshop on moving frames which will take place shortly at the centre de recherches mathematiques at the Universite de Montreal.

Abe has been an exemplary colleague, from whom I have learned a lot over the past two years. I will greatly miss our weekly scientific discussions when he leaves. I am delighted that he has found a position at Fordham; I expect that when his current project will have been written up and published in a first-rate journal, as I expect it will be, Abe will be in high demand on the job market.

I would like to take this opportunity to thank the MSRI and the NSF for having created the Postdoctoral Fellowships program that Abe was able to benefit from. In Abe's case, it has certainly been a remarkable success.

Sincerely,

Niky Kamran
James McGill Professor of Mathematics
McGill University

MSRI FINAL REPORT

JARED SPECK

1. Background Information

- Year of Ph.D: 2008
- Institution of Ph.D.: Rutgers University
- Ph.D. advisors: Michael Kiessling and A. Shadi Tahvildar-Zadeh

- Institution prior to obtaining the MSRI PD fellowship: Princeton University
- Position at that institution: Lecturer
- Mentors: Sergiu Klainerman (Princeton University), Igor Rodnianski (Princeton University), Mihalis Dafermos (University of Cambridge)

- Institution where you held your MSRI PD fellowship: Princeton University
- Mentor at that institution: Sergiu Klainerman

- Institution where you are going next year: MIT
- Position: Assistant Professor
- Anticipated length: Tenure-track

2. Summary of Recent Activities

Here is a brief summary of the activities that I carried out in 2011 under the auspices of the NSF/MSRI fellowship.

- I applied for tenure-track positions and accepted a tenure-track Assistant Professorship position at MIT.
- I submitted two papers for publication.
- I helped run the analysis seminar at Princeton.
- I mentored/supervised a Princeton undergraduate during the writing of his senior math thesis.
- I traveled to Paris and England to deliver a series of lectures.
- I initiated work on some new projects.
- I applied for some grants from MIT.

E-mail address: `jspeck@math.princeton.edu`

Department of Mathematics
Princeton University
Fine Hall, Washington Road
Princeton, NJ 08544-1000

July 12, 2011

MSRI Postdoctoral Fellowship
17 Gauss Way
Berkeley, CA 94720-5070

To Whom It May Concern:

As requested, I am writing to provide a brief report regarding Jared Speck's professional progress as an MSRI Postdoctoral Fellow. Here is a brief summary of his recent activities.

- Has submitted two very good papers for publication based in part on his work in Princeton during his fellowship.
- Has played an important role in running the analysis seminar in Princeton.
- He has mentored a Princeton undergraduate for his senior thesis.
- Has travelled to Paris and Cambridge to deliver lectures and work with people there.
- Has successfully applied for a tenure track position. Starting this fall he will be assistant professor at MIT.

To conclude Speck has done very well during his year at Princeton; his MSRI postdoctoral fellowship has been really useful as meant, i.e. it allowed Speck to develop his scientific career and help him find a tenure tracked job .

Sincerely,

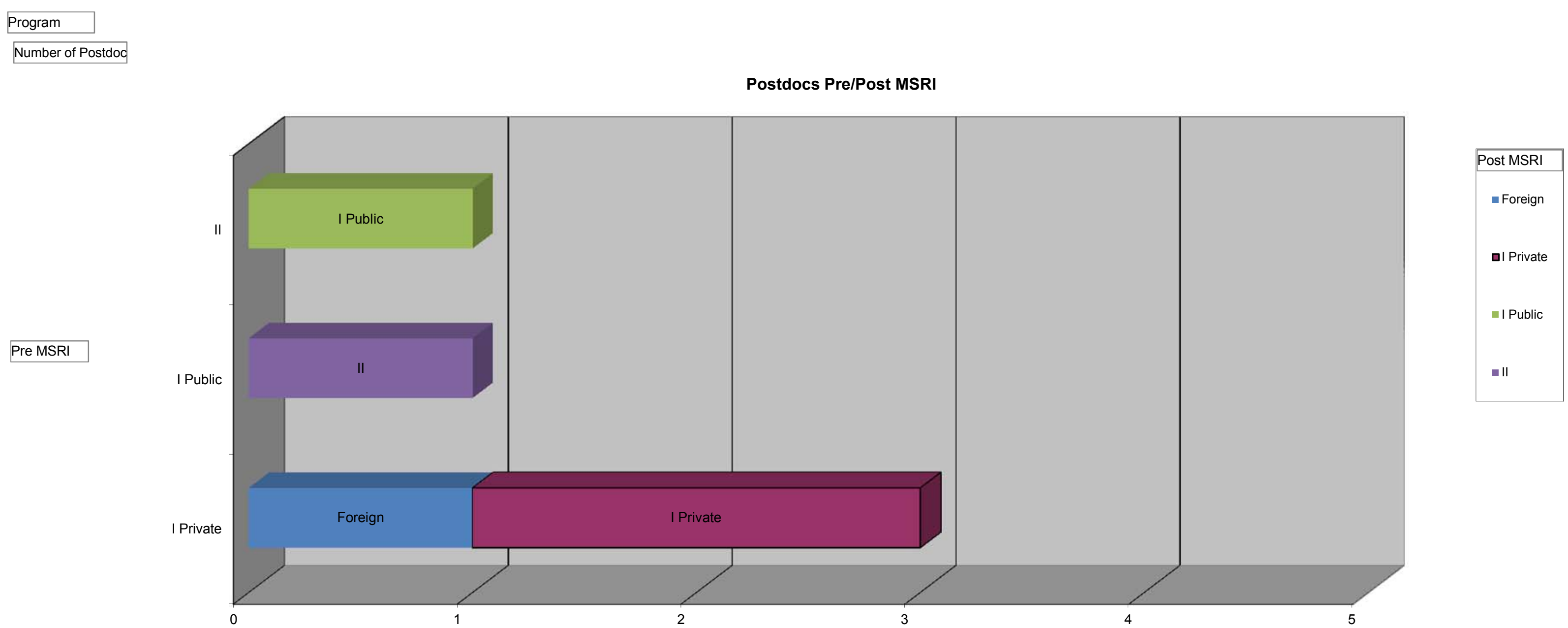
Sergiu Klainerman

External Postdoctoral Fellows 2009-10

Postdoctoral Fellows Pre/Post MSRI

Institution Groups based on AMS classification

				Institute				*AMS Groups*		
Activity	***Family Name***	***First Name***	***Year Ph.D.***	***Degree***	***Pre MSRI***	***Placement/Post MSRI***	***Position***	***Degree***	***Pre MSRI***	***Post MSRI***
External PD 09-10	Angeltveit	Vigleik	2006	MIT	University of Chicago	University of Chicago	Postdoc	I Private	I Private	I Private
External PD 09-10	Crofts	Scott	2009	University of Utah	University of Utah	UC Santa Cruz	Postdoc	I Public	I Public	II
External PD 09-10	Hillar	Christopher	2005	UC Berkeley	Texas A&M University	Redwood Center for Theoretical Neuroscience	Postdoc	I Public	II	I Public
External PD 09-10	Mahlburg	Karl	2006	University of Wisconsin at Madison	MIT	Princeton University	Postdoc	I Public	I Private	I Private
External PD 09-10	Smith	Abraham	2009	Duke University	Duke University	McGill University	Postdoc	I Private	I Private	Foreign



External Program 2009-10
Program Summary

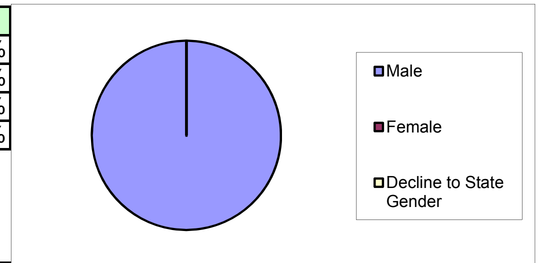
Role	# of Distinct Members	%	# of Citizens & Perm. Res.	%	# of Female	%	# of Minorities	%
Organizers	0	*0.0%*	0	*0.0%*	0	*0.0%*	0	*0.0%*
Research Professors	0	*0.0%*	0	*0.0%*	0	*0.0%*	0	*0.0%*
Postdoctoral Fellows	5	*100.0%*	5	*100.0%*	0	*0.0%*	1	*20.0%*
PD/RM	0	*0.0%*	0	*0.0%*	0	*0.0%*	0	*0.0%*
Research Members	0	*0.0%*	0	*0.0%*	0	*0.0%*	0	*0.0%*
Program Associates	0	*0.0%*	0	*0.0%*	0	*0.0%*	0	*0.0%*
Guests	0	*0.0%*	0	*0.0%*	0	*0.0%*	0	*0.0%*
Total no. of Distinct Members	**5**	***100.0%***	**5**	***100.0%***	**-**	***0.0%***	**1**	***20.0%***

Home Institute Grouping

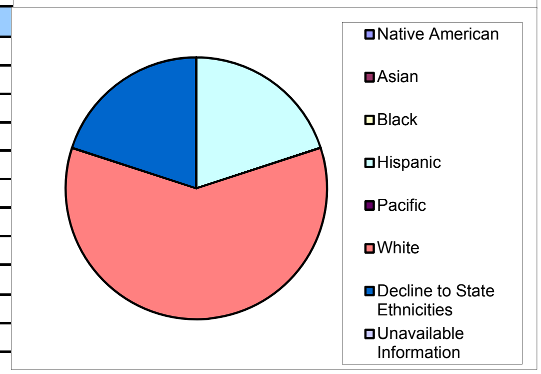
Role	Foreign	Group I Private	Group I Public	Group II	Group III	Group M	Non-Group	Total
Organizers								0
Research Professors								0
Postdoctoral Fellows		3	1	1				5
PD/RM								0
Research Members								0
Program Associates								0
Guests								0
Total	**-**	**3**	**1**	**1**	**-**	**-**	**-**	**5**
%	***0.0%***	***60.0%***	***20.0%***	***20.0%***	***0.0%***	***0.0%***	***0.0%***	***100.0%***

External Postdoctoral Fellows 2009-10 Demographic Summary

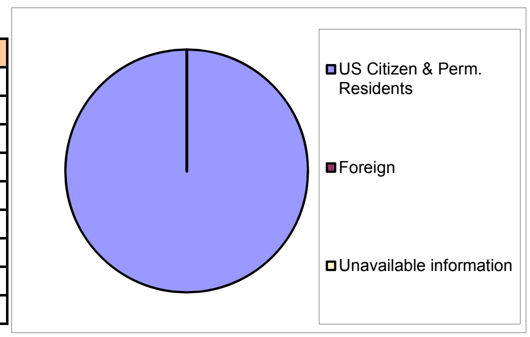
Gender	#	% (No Decl.)*	%
No. of Distinct Members	5		100.0%
Male	5	100.00%	100.0%
Female	0	0.00%	0.0%
Decline to State Gender	0		0.0%



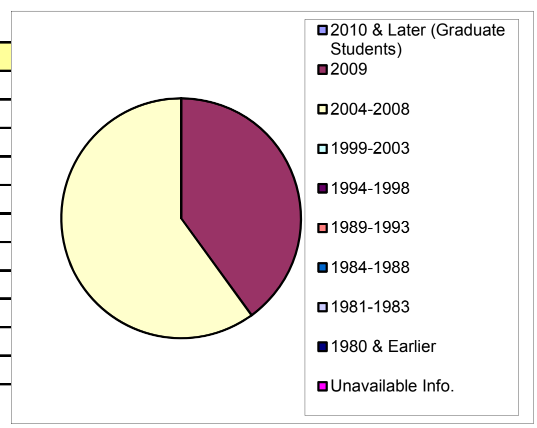
Ethnicities	#	% (No Decl.)*	%
Native American	0	0.00%	0.0%
Asian	0	0.00%	0.0%
Black	0	0.00%	0.0%
Hispanic	1	25.00%	20.0%
Pacific	0	0.00%	0.0%
White	3	75.00%	60.0%
Decline to State Ethnicities	1		20.0%
Unavailable Information	0		0.0%
No. of Distinct Members	5		100.0%
Minorities	1		20.0%



Citizenships	#		%
US Citizen & Perm. Residents	5		100.0%
Foreign	0		0.0%
Unavailable information	0		0.0%
No. of Distinct Members	5		100.0%
US Citizen	4		80.0%
Perm Residents	1		20.0%
Home Inst. in US	5		100.00%



Year of Ph.D	#		%
2010 & Later (Graduate Students)	0		0.0%
2009	2		40.0%
2004-2008	3		60.0%
1999-2003	0		0.0%
1994-1998	0		0.0%
1989-1993	0		0.0%
1984-1988	0		0.0%
1981-1983	0		0.0%
1980 & Earlier	0		0.0%
Unavailable Info.	0		0.0%
Total	5		100.0%



**Statistic Calculation based on all participants that did not decline.*

Connections for Women – Tropical Geometry

MSRI Berkeley, August 22 & 23, 2009

Organizers: Alicia Dickenstein, Eva-Maria Feichtner

The 2-days Connections for Women workshop was the very first event of the then upcoming fall program on Tropical Geometry at MSRI. It was organized back to back with the 5-days Introductory Workshop of the program. Both events being of an introductory nature, close collaboration of the organizing teams resulted in complementary programs of both mini-courses and research talks and brought the financial resources for both events to an optimal use. We were able to support a high number of young, female participants, enabling them to familiarize themselves with tropical geometry and providing them with manifold networking opportunities both with women mathematicians and throughout the tropical community as a whole.

Scientific description

Recent years have seen a tremendous development in Tropical Geometry that both established the field as an area of its own right and unveiled its deep connections to numerous branches of pure and applied mathematics. Formally speaking, Tropical Geometry is the algebraic geometry over the tropical semiring $\mathbb{R}\cup\{\infty\}$ with arithmetic operations $x \oplus y := \min\{x, y\}$ and $x \odot y := x+y$. From an algebraic geometric point of view, algebraic varieties over a field with non-archimedean valuation are replaced by polyhedral complexes, thereby retaining much of the information about the original varieties. From the point of view of complex geometry, the geometric combinatorial structure of tropical varieties is a maximal degeneration of a complex structure on a manifold.

The tropical transition from the objects of algebraic geometry to the polyhedral realm is an extension of the familiar theory of toric varieties. It opens classical problems to a completely new set of techniques, and has already led to remarkable results in Enumerative Algebraic Geometry, Symplectic Geometry, Dynamical Systems and Computational Commutative Algebra, among other fields, and to applications in Algebraic Statistics, Mathematical Biology, and Statistical Physics.

Mini-courses and talks

The Connections for Women event featured two mini-courses of two 1-hour lectures each. The mini-courses were addressed to newcomers to the field of Tropical Geometry and provided accessible as well as intriguing introductions from different viewpoints. For both mini-courses, selected exercises were provided and the lecturers were available for discussions of the problems during the workshop.

Federico Ardila (San Francisco State University): *Linearity in the tropics*

Abstract: Tropical geometry studies an algebraic variety X by 'tropicalizing' it into a polyhedral complex Trop(X) which retains some information about X. Tropical varieties may be simpler than algebraic varieties, but they are by no means well understood. In fact, tropical linear spaces already feature a surprisingly rich and beautiful combinatorial structure, and interesting connections to geometry, topology, and phylogenetics. I will discuss what we currently know about them.

In the first lecture, I will give an introduction to matroids, and explain how they describe the local structure of a tropical linear space, both combinatorially and topologically. In the second lecture, I will explain the correspondence between tropical linear spaces and the subdivisions of a matroid polytope into smaller matroid polytopes, and discuss the tropical Grassmannian.

Hannah Markwig (Courant Research Center, U Göttingen): *Counting tropical plane curves*

Abstract: In this course, we introduce the basics of tropical enumerative geometry. In the first lecture, we introduce tropical plane curves as images of Puiseux series curves under the valuation map and investigate their combinatorial structure. We introduce the lattice path algorithm to count tropical plane curves. In the second lecture, we investigate the relation between lattice paths and tropical plane curves. We introduce some examples of moduli spaces of tropical curves and explain how they can be used to count tropical curves.

The mini-courses were complemented with five 40-minute lectures and a session of short contributions by participants. This laid out an even broader picture of Tropical Geometry and provided glimpses on ongoing research.

40-minute lectures:

- Josephine Yu (MSRI): *Tropical varieties, elimination, and mixed fiber polytopes*
- Lucía López de Medrano (MSRI): *Tropical inflection points of tropical planar curves*
- Annette Werner (U Frankfurt): *Buildings and tropical geometry*
- Marianne Akian (INRIA): *Tropical linear independence and symmetrization of the tropical semiring*
- Lauren Williams (UC Berkeley): *The tropical Grassmannian and its positive part*

20-minute lectures:

- Thomas Markwig (U Kaiserslautern): *The tropical j-invariant*
- Kirsten Schmitz (U Osnabrück): *On Generic Tropical Varieties*
- Anne Shiu (UC Berkeley): *Systems biology and tropical geometry*

Career issues of female mathematicians

Besides the many informal networking opportunities for the participating women both between talks and during the sponsored women's dinner Saturday evening, we organized a panel discussion on career issues. The following women served as panelists:

- Hélène Barcelo (full professor, Arizona State University / deputy director, MSRI)
- Maria Angelica Cueto (graduate student, UC Berkeley)
- Diane Maclagan (associate professor, U of Warwick)
- Lauren Williams (assistant professor,UC Berkeley)
- Josephine Yu (Postdoc, NSF, MSRI)

Career related topics for young mathematicians were as well a matter of discussion as general issues of women working as mathematicians in academia (family and dual career issues, work/life balance). The panel was very well attended. With the hope of furthering questions and discussions we chose the dining area as venue - an overcrowded room hosting a most lively event was the best proof of its success.

Connections for Women: Tropical Geometry

Invited Speakers

Dickenstein, Alicia M.	University of Buenos Aires
Feichtner, Eva Maria	Universität Bremen
Lopez de Medrano, Lucia	National Autonomous University of Mexico (UNAM)
Werner, Annette	Johann Wolfgang Goethe-Universität Frankfurt
Williams, Lauren Kiyomi	Harvard University
Akian, Marianne	INRIA and Ecole Polytechnique
Markwig, Hannah	Georg-August-Universität zu Göttingen
Ardila, Federico	San Francisco State University

MSRI Mathematical Sciences Research Institute

Connections for Women:

Tropical Geometry

August 22 - 23, 2009

Saturday August 22, 2009		
09:00AM - 09:30AM	Coffee, registration, welcome	
09:30AM - 10:30AM	Federico Ardila	Minicourse: Linearity in the tropics I
10:30AM - 11:00AM	Coffee break	
11:00AM - 12:00PM	Hannah Markwig	Minicourse: Counting tropical plane curves I
12:00PM - 02:00PM	Lunch	
02:00PM - 02:40PM	Josephine Yu	Tropical varieties, elimination, and mixed fiber polytopes
02:50PM - 03:30PM	Lucia Lopez de Medrano	Tropical inflection points of tropical planar curves
03:30PM - 04:00PM	Tea	
04:00PM - 05:00PM	Hélène Barcelo, Maria Angelica Cueto, Diane Maclagan, Lauren Williams, Josephine Yu	Panel discussion on career issues of female mathematicians
06:30PM - 08:30PM	Dinner	
Sunday August 23,2009		
09:00AM - 09:30AM	Discussion of exercises of the minicourses (Informal)	
09:30AM - 10:30AM	Federico Ardila	Minicourse: Linearity in the tropics II
10:30AM - 11:00AM	Coffee break	
11:00AM - 12:00PM	Hannah Markwig	Minicourse: Counting tropical plane curves II
12:00PM - 02:00PM	Lunch	
02:00PM - 02:40PM	Annette Werner	Buildings and tropical geometry
02:50PM - 03:30PM	Marianne Akian	Tropical linear independence and symmetrization of the tropical semiring
03:30PM - 04:00PM	Tea	
04:00PM - 04:50PM	Thomas Markwig, Kirsten Schmitz, Anne Shiu	Short talks
05:00PM - 05:40PM	Lauren Williams	The tropical Grassmannian and its positive part
05:50PM - 06:00PM	Closing	

Currently Available Videos

- **Federico Ardila** , Minicourse: Linearity in the tropics I *August 22,2009, 09:30 AM to 10:30 AM*
- **Hannah Markwig** , Minicourse: Counting Tropical plane curves I *August 22,2009, 11:00 AM to 12:00 PM*
- **Josephine Yu** , Tropical Varities, elimination, and mixed fiber polytypes *August 22,2009, 02:00 PM to 02:40 PM*
- **Lucia Lopez de Medrano** , Tropical inflection points of tropical planar curves *August 22,2009, 02:50 PM to 03:30 PM*
- **Federico Ardila** , Minicourse: Linearity in the tropics II *August 23,2009, 09:30 AM to 10:30 AM*
- **Hannah Markwig** , Minicourse: Counting tropical plane curves II *August 23,2009, 11:00 AM to 12:00 PM*
- **Annette Werner** , Buildings and tropical geometry *August 23,2009, 02:00 PM to 02:40 PM*
- **Marianne Akian** , Tropical linear independence and symmetrization of the tropical semiring *August 23,2009, 02:50 PM to 03:30 PM*
- **Thomas Markwig, Kirsten Schmitz, Anne Shiu** , Short talks *August 23,2009, 04:00 PM to 05:00 PM*
- **Thomas Markwig, Kirsten Schmitz, Anne Shiu** , Short talks *August 23,2009, 04:00 PM to 05:00 PM*
- **Thomas Markwig, Kirsten Schmitz, Anne Shiu** , Short talks *August 23,2009, 04:00 PM to 05:00 PM*
- **Lauren Williams** , The tropical Grassmannian and its positive part *August 23,2009, 05:00 PM to 05:50 PM*

You can find videos of other workshops and events on our VMath - Streaming Video page.

Participant List

MSRI Workshop:

Connections for Women: Tropical Geometry

August 22-23, 2009

at Mathematical Sciences Research Institute, Berkeley California

Name	Institution
Akian, Marianne	INRIA and Ecole Polytechnique
Ardila, Federico	San Francisco State University
Aroca, Fuensanta	National Autonomous University of Mexico (UNAM)
Assaf, Sami H	Massachusetts Institute of Technology
Barcelo, Hélène	MSRI - Mathematical Sciences Research Institute
Benedetti, Carolina	University of Los Andes
Berkesch, Christine M.	Department of Mathematics
Beshaj, Lubjana	Department of Mathematics, University of Vlora
bidkhori, hoda	Massachusetts Institute of Technology
Block, Florian	University of Michigan
Bogart, Tristram Charles	Queen's University
Buchholz, Arne	Georg-August-Universität zu Göttingen
Buczynska, Weronika Julia	Texas A & M University
Cartwright, Dustin	University of California
Chan, Melody	University of California
chavez, Anastasia maria	San Francisco State University
Chen, Chen-wei	National Cheng Chi University
Cotterill, Ethan Guy	Max-Planck-Institut für Mathematik
Cueto, Maria Angelica	University of California
de Wolff, Timo	Johann Wolfgang Goethe-Universität Frankfurt
Degany, Yael	University of California
Dickenstein, Alicia M.	University of Buenos Aires
Eisenbud, David	UC Berkeley Math Faculty
Escobar, Laura	San Francisco State University
Evans, Addie Andromeda	San Francisco State University
Feichtner, Eva Maria	Universität Bremen
Feichtner-Kozlov, Dmitry N.	Universität Bremen
Fink, Alex	University of California
Freeman, Kristen Dawn	University of California
Gaubert, Stephane Louis	École Polytechnique
Gegenberg, Thea	University of Waterloo
Gunturkun, Mustafa Hakan	University of Oregon
Haebich, Mathias	Johann Wolfgang Goethe-Universität Frankfurt
Harris, Kelley	University of California
Hept, Kerstin Verena Sonja	Johann Wolfgang Goethe-Universität Frankfurt
Hering, Milena	University of Connecticut
Hoxhaj, Valmira	Department of Mathematics, University of Vlora
HUANG, Yi	Georgia Institute of Technology
Iriarte, Benjamin	San Francisco State University
Jensen, Anders Nedergaard	Georg-August-Universität zu Göttingen
Jeronimo, Gabriela Talí	University of Buenos Aires
Johansson, Petter	The Mathematical Sciences Research Institute
Johns, Joseph Amos	Columbia University
Kang, Ning	University of Texas
Karaali, Gizem	Pomona College
Karshon, Yael	University of Toronto
Kedzierska, Anna Magdalena	University of California
Kong, Nayeong	Pusan National University
Kosova, Ervisa	Department of Mathematics, University of Vlora
Kuo, Jung-Miao	University of Montana
Lagerberg, Aron Freyr	Aron Lagerberg
Lakhani, Chirag Manmohan	North Carolina State University
Leykin, Anton	Georgia Institute of Technology

Liu, Fu	University of California
Lopez de Medrano, Lucia	National Autonomous University of Mexico (UNAM)
Lundqvist, Johannes	University of Stockholm
Maclagan, Diane	University of Warwick
Marciniak, Malgorzata Aneta	University of Missouri
Markwig, Hannah	Georg-August-Universität zu Göttingen
Markwig, Thomas Ewald	Mathematisches Institut, Georg-August-Universität Göttingen
Munguia, Erendira	National Autonomous University of Mexico (UNAM)
Musiker, Gregg	MIT, Department of Mathematics
Nairn, Kristen Ann	St. John's University
Nesci, Michele	Université de Genève
Nill, Benjamin Thorsten	Mathematical Institute, Freie Universitaet Berlin
Nilsson, Lisa Maria	Stockholm University
Nisse, Mounir	Université de Paris VI (Pierre et Marie Curie)
Oliveira, Taise Santiago Costa	Federal University of Bahia
Owen, Megan	North Carolina State University
Pate, Kevin Jang	Oakland University
Rincon, Felipe	University of California
Ruiz, Amanda	Binghamton University (SUNY)
Rutgayzer, Margarita	Humboldt-Universität
Salamar-Torres, Dido	San Francisco State University
Schmitz, Kirsten	Universitaet Osnabrueck
Schroeter, Franziska	Georg-August-Universität zu Göttingen
Seceleanu, Alexandra	University of Illinois at Urbana-Champaign
Severs, Christopher	Arizona State University
Shaker, Hani	COMSATS Institute of Information Technology, Lahore, Pakistan.
Shaw, Kristin Marie	University of Toronto
Shiu, Anne J.	University of California
Sottile, Frank	Texas A & M University
Stapledon, Alan Michael	University of Michigan
Tabera, Luis Felipe	University of California
Taipale, Kaisa	University of Minnesota Twin Cities
Talaska, Kelli	University of Michigan
Vazirani, Monica Joy	UC Davis
Viray, Bianca	University of California
Vu, Thanh Quang	University of California
Walker, Björn	
Werner, Annette	Johann Wolfgang Goethe-Universität Frankfurt
Williams, Lauren Kiyomi	Harvard University
Wu, Weiwei	University of Minnesota Twin Cities
Wulcan, Elizabeth	Department of Mathematics, University of Michigan
Yang, Jihyeon Jessie	University of Toronto
Youtz, Ralf	San Francisco State University
Yu, Josephine T.	Massachusetts Institute of Technology

Connections for Women: Tropical Geometry
Held: August 22-23, 2009
The Mathematical Sciences Research Institute

Officially Registered Participant Information
97 participants

Gender (n = 97participants)		
Male	32.99%	32
Female	67.01%	65
Declined to state	0.00%	0

Ethnicity (n =95 participants)		
White	67.37%	64
Asian	20.00%	19
Hispanic	10.53%	10
Pacific Islander	1.05%	1
Black	0.00%	0
Native American	1.05%	1
Declined to state	0.00%	0

REPORT ON THE MSRI INTRODUCTORY WORKSHOP OF THE PROGRAM "TROPICAL GEOMETRY"

August 24 - 28, 2009

Organizers: Eva-Maria Feichtner, Ilia Itenberg, Grigory Mikhalkin and Bernd Sturmfels

1. Scientific description

The main purpose of this workshop was to lay the foundations for the beginning MSRI fall program "Tropical Geometry." Tropical Geometry is a branch of geometry that has appeared just recently. Formally, it can be viewed as Algebraic Geometry over the semiring of tropical numbers. The *tropical numbers* are the real numbers enhanced with negative infinity and equipped with two arithmetic operations called *tropical addition* and *tropical multiplication*. The tropical addition is the operation of taking the maximum. The tropical multiplication is the conventional addition. These operations are commutative, associative and satisfy the distribution law. The term "tropical" was coined by computer scientists and is a tribute to Brazil, in particular the contributions of the Brazilian mathematician Imre Simon to the theory of formal languages.

It turns out that tropical algebra describes some meaningful geometric objects, namely, Tropical Varieties. From the topological point of view tropical varieties are polyhedral complexes equipped with a particular geometric structure coming from tropical algebra. From the point of view of Complex Geometry this geometric structure is the worst possible degeneration of complex structure on a manifold. From the point of view of Symplectic Geometry a tropical variety is the result of a Lagrangian collapse of a symplectic manifold along a singular fibration by Lagrangian tori.

Tropical Geometry has applications in Real Algebraic Geometry, Enumerative Geometry, Mirror Symmetry, Symplectic Geometry, as well as Combinatorial and Computational Geometry, while the list of its applications keeps growing. E.g., Tropical Geometry made a most recent and brand-new appearance in the Statistical Physics work of R. Kenyon and A. Okounkov where they studied mathematical models for dimers accumulation. Currently there are several research groups around the globe who are doing active research in Tropical Geometry from somewhat different points of view.

With this introductory workshop we were able to portray a substantial part of this evolving field through mini-courses and through complementing research talks, thereby providing both an entrance point for newcomers to the field and a point of outset for those who came to attend the program.

In five mini-courses of three 1-hour lectures each, the foundational aspects of Tropical Geometry were covered as well as its connections with adjacent areas: Algebraic Geometry, Geometric

Combinatorics, Several Complex Variables and Symplectic Geometry. Notably, the mini-course by Denis Auroux, a key participant of the parallel MSRI program “Symplectic and Contact Geometry and Topology” drew a lot of attention from both programs and provided a bridge for future joint activities.

The mini-courses were augmented by five research talks on current developments in Tropical Geometry which opened the scene and set up new goals for the beginning semester.

As the breadth of the topic suggests, the workshop drew participants from a large variety of areas. Close coordination with the organizers of the 2-days “Connections for Women” Workshop immediately preceeding the Introdutory Workshop enabled us to fund a large number of young participants who then stayed for both events.

2. Highlights of presentations

Mini-courses

The goal of the mini-course of D. Auroux was to explain how tropical geometry naturally appears in various parts of mirror symmetry. The starting point was the geometry of special Lagrangian fibrations and its description in terms of singular affine structures. D. Auroux showed how in this context tropical curves can be interpreted both as complex curves (on the complex side of the mirror) and as Lagrangian submanifolds (on the symplectic side). Then, he explained how holomorphic discs, and their count via tropical techniques, determine superpotentials and instanton corrections to the mirror geometry. The main examples were elementary ones: toric varieties (in particular the complex projective plane), abelian varieties, K3 surfaces.

The mini-course of I. Itenberg was devoted to real aspects of tropical geometry, and in particular, to combinatorial patchworking. This procedure is one of the sources of tropical geometry and is a particular case of the Viro method of construction of real algebraic varieties with prescribed topology. Combinatorial patchworking allows one to construct real algebraic varieties in a combinatorial fashion: one can patchwork them from pieces which essentially are hyperplanes. I. Itenberg presented several applications of combinatorial patchworking and discussed its relations with tropical geometry.

The mini-course of D. Maclagan was devoted to the basics of tropical algebraic geometry. Tropical varieties considered in this mini-course are tropicalizations of subvarieties of an algebraic torus. Many invariants of (compactifications of) the original variety can be computed from the tropical variety. The mini-course focused on the multiple alternate descriptions of a tropical variety (via valuations or Gröbner bases or polyhedral geometry), and the combinatorial constraints on a tropical variety.

The mini-course of M. Passare was an introduction to the theory of complex (co)amoebas. An *amoeba* is the logarithmic image of an algebraic subvariety of a torus. This notion was introduced in 1994 by I. Gelfand, M. Kapranov, and A. Zelevinsky, and the analytic treatment of amoebas of complex varieties was done in the works of M. Forsberg, M. Passare, H. Rullgård, T. Sadykov, and A. Tsikh. Amoebas are directly related to tropical varieties. Kapranov showed that the amoebas of hypersurfaces over non-Archimedian fields can be represented by tropical hypersurfaces (further developments of this important observation were done by M. Einsiedler, M. Kapranov, and D. Lind). The amoeba of a complex hypersurface has a “spine” which is a tropical variety. The connection between amoebas and tropical varieties plays a crucial role in the proof of Mikhalkin’s correspondence theorem.

J. Tevelev explained in his mini-course that tropical algebraic geometry offers new tools for elimination theory and implicitization. The necessary background in algebraic geometry was explained and many examples were discussed. The main point was the interpretation of implicitization as the process of building semi-stable models of algebraic varieties by means of suitable compactifications.

Talks

G. Mikhalkin presented in his talk the basic notions of tropical geometry, namely, tropical varieties and maps between them.

The talk of J.-J. Risler was devoted to real algebraic geometry, and more precisely, to a universal inequality between the total curvatures of an affine real variety and its complexification. J.-J. Risler also discussed similar inequalities and their sharpness in various cases: algebraic, local analytic, amoebas of curves, smooth tropical varieties.

A. Dickenstein presented an alternative approach to the implicitization of rational varieties using tropical tools, reporting on her joint research with B. Mourrain.

M. Abouzaid showed how tropical geometry provides a powerful tool for constructing Lagrangian objects, such as immersed Lagrangian spheres and Lagrangian skeleta. Such constructions shed light to some geometric aspects of Mirror Symmetry.

M. Gross gave a lecture on his work on constructing canonical theta functions for Calabi-Yau manifolds. This work is a part of his research program with B. Siebert on mirror symmetry.

All the mini-courses and talks were well-received by the many participants, most of whom were young mathematicians (graduate students and postdocs). In addition to the formal sessions, we witnessed a large number of exciting informal interactions among the workshop participants.

Introductory Workshop: Tropical Geometry

Invited Speakers

Feichtner, Eva Maria	Universität Bremen
Itenberg, Ilia	Institut de Recherche Mathématique Avancée de Strasbourg
Mikhalkin, Grigory	Université de Genève
Sturmfels, Bernd	UCB - University of California, Berkeley
Abouzaid, Mohammed	MIT
Auroux, Denis	University of California
Gross, Mark W.	University of California, San Diego
Maclagan, Diane	University of Warwick
Passare, Mikael	University of Stockholm
Risler, Jean-Jacques	Université de Paris VI (Pierre et Marie Curie)
Tevelev, Evgueni	University of Massachusetts
Viro, Oleg	SUNY

MSRI Mathematical Sciences Research Institute

Introductory Workshop:

Tropical Geometry

August 24, 2009 to August 28, 2009

Monday August 24, 2009		
09:00AM - 09:15AM	Welcome	
09:15AM - 10:15AM	Ilia Itenberg	Real aspects of tropical geomerty I
10:15AM - 11:00AM	Coffee, tea in the atrium	
11:00AM - 12:00PM	Mikael Passare	Complex amoebas and coamoebas I
12:00PM - 02:00PM	Lunch	
02:00PM - 03:00PM	Diane Maclagan	Introduction to tropical algebraic geometry I
03:00PM - 04:00PM	Coffee, tea in the atrium	
04:00PM - 05:00PM	Grigory Mikhalkin	Basic tropical notions: varieties and maps
Tuesday August 25, 2009		
09:30AM - 10:30AM	Ilia Itenberg	Real aspects of tropical geomerty II
10:30AM - 11:00AM	Coffee, tea in the atrium	
11:00AM - 12:00PM	Diane Maclagan	Introduction to tropical algebraic geometry II
12:00PM - 02:00PM	Lunch	
02:00PM - 03:00PM	Evgueni Tevelev	Tropical Elimination Theory I
03:00PM - 04:00PM	Coffee, tea in the atrium	
04:00PM - 05:00PM	Jean-Jacques Risler	Real Algebraic Geometry, Tropical Geometry and Total Curvature
05:00PM - 06:00PM	Reception in the atrium	
Wednesday August 26, 2009		
09:30AM - 10:30AM	Mikael Passare	Complex amoebas and coamoebas II
10:30AM - 11:00AM	Coffee, tea in the atrium	
11:00AM - 12:00PM	Evgueni Tevelev	Tropical Elimination Theory II
12:00PM - 02:00PM	Lunch	
02:00PM - 03:00PM	Denis Auroux	Some tropical aspects of mirror symmetry I
03:00PM - 04:00PM	Coffee, tea in the atrium	
04:00PM - 05:00PM	Alicia Dickenstein	A naive approach to the implicitization of rational varieties using tropical tools
Thursday August 27, 2009		
09:30AM - 10:30AM	Ilia Itenberg	Real aspects of tropical geomerty III
10:30AM - 11:00AM	Coffee, tea in the atrium	
11:00AM - 12:00PM	Diane Maclagan	Introduction to tropical algebraic geometry III
12:00PM - 02:00PM	Lunch	
02:00PM - 03:00PM	Denis Auroux	Some tropical aspects of mirror symmetry II
03:00PM - 04:00PM	Coffee, tea in the atrium	
04:00PM - 05:00PM	Mohammed Abouzaid	Symplectic perspectives on tropical geometry
Friday August 28, 2009		
09:30AM - 10:30AM	Mikael Passare	Complex amoebas and coamoebas III
10:30AM - 11:00AM	Coffee, tea in the atrium	
11:00AM - 12:00PM	Evgueni Tevelev	Tropical Elimination Theory III
12:00PM - 02:00PM	Lunch	
02:00PM - 03:00PM	Denis Auroux	Some tropical aspects of mirror symmetry III
03:00PM - 04:00PM	Coffee, tea in the atrium	
04:00PM - 05:00PM	Mark Gross	Towards canonical theta functions for Calabi-Yaus

Currently Available Videos

- **Sam Payne** , Topology of compactified tropicalizations *October 12,2009, 09:30 AM to 10:30 AM*
- **Alex Esterov** , Newton polyhedra and Minkowski integrals. *October 12,2009, 11:00 AM to 12:00 PM*
- **Eric Katz** , Realization Spaces for Tropical Varieties *October 12,2009, 02:00 PM to 03:00 PM*
- **Arkady Berenstein** , Geometric crystals and tropical combinatorics *October 13,2009, 09:30 AM to 10:30 AM*
- **Gleb Koshevoy** , Bases of tropical Plucker functions, wirings, tilings and Leclerc-Zelevinsky conjectures. *October 13,2009, 11:00 AM to 12:00 PM*
- **Filip Cools** , Tropical geometry and dissimilarity vectors of trees *October 13,2009, 02:00 PM to 03:00 PM*
- **Daniele Alessandrini** , Tropicalization of Teichmuller spaces *October 13,2009, 04:00 PM to 05:00 PM*
- **Walter Gubler** , Tropical analytic geometry and the Bogomolov conjecture *October 14,2009, 09:00 AM to 10:00 AM*
- **Josephine Yu** , Linear Systems on Tropical Curves *October 14,2009, 10:30 AM to 11:30 AM*
- **Diane Maclagan** , Tropical bounds on effective cycles *October 14,2009, 11:45 AM to 12:45 PM*
- **Matthew Baker** , Metric properties of the tropical Abel-Jacobi map *October 15,2009, 09:30 AM to 10:30 AM*
- **Filippo Viviani** , On the tropical Torelli map *October 15,2009, 11:00 AM to 12:00 PM*
- **Sergey Fomin** , Enumeration of plane curves and labeled floor diagrams *October 15,2009, 02:00 PM to 03:00 PM*
- **Michael Joswig** , Coarse tropical convexity and cellular resolutions *October 16,2009, 09:30 AM to 10:30 AM*
- **Michael Joswig** , Brief Software Tutorial *October 16,2009, 10:30 AM to 11:00 AM*
- **Thorsten Theobald** , Combinatorics and genus of tropical intersections and Ehrhart theory *October 16,2009, 11:00 AM to 12:00 PM*
- **Alex Fink** , Tropical cycles and Chow polytopes *October 16,2009, 02:00 PM to 03:00 PM*
- **Annette Werner** , Buildings and tropical geometry *October 16,2009, 04:00 PM to 05:00 PM*You can find videos of other workshops and events on our VMath - Streaming Video page.

Participant List

MSRI Workshop:

Introductory Workshop: Tropical Geometry

August 24-28, 2009

at Mathematical Sciences Research Institute, Berkeley California

Name	Institution
Abouzaid, Mohammed	MIT
Adachi, Jiro	Hokkaido University
Akian, Marianne	INRIA and Ecole Polytechnique
Ardila, Federico	San Francisco State University
Assaf, Sami H	Massachusetts Institute of Technology
Atingabunor, George Amoah	Khomanani Business College
Auroux, Denis	University of California
Azimian, Amin	Islamic Azad University,South Tehran
Beck, Matthias	San Francisco State University
Berkesch, Christine M.	Department of Mathematics
bidkhori, hoda	Massachusetts Institute of Technology
Block, Florian	University of Michigan
Bogart, Tristram Charles	Queen's University
Brodsky, Sarah	University of California
Brodsky, Sarah	University of California
Buchholz, Arne	Georg-August-Universität zu Göttingen
Buczynska, Weronika Julia	Texas A & M University
Cartwright, Dustin	University of California
Castano-Bernard, Ricardo	Kansas State University
Chan, Melody	University of California
Chen, Chen-wei	National Cheng Chi University
Christensen, Chris	TU Dortmund / Fakultät für Mathematik
Cooper, Daryl	University of California
Cornea, Octav	University of Montreal
Cotterill, Ethan Guy	Max-Planck-Institut für Mathematik
Cueto, Maria Angelica	University of California
De Oliveira, Wellington	Federal University of Paraíba
de Wolff, Timo	Johann Wolfgang Goethe-Universität Frankfurt
Devadoss, Satyan Linus	Williams College
Dickenstein, Alicia M.	University of Buenos Aires
Diemer, Colin	University of Pennsylvania
Diogo, Luis Miguel	Stanford University
Draisma, Jan	Technische Universiteit Eindhoven
Eisenbud, David	UC Berkeley Math Faculty
Erman, Daniel Max	University of California
Faber, Xander W. C.	McGill University
Farajzadeh Tehrani, Mohammad	Princeton University
Feichtner, Eva Maria	Universität Bremen
Fink, Alex	University of California
Francois, Georges	TU Kaiserslautern
Frenk, Bart	Technische Universiteit Eindhoven
Ganatra, Sheel	Massachusetts Institute of Technology
Gathmann, Andreas	University of Kaiserslautern
Gaubert, Stephane Louis	École Polytechnique
Gegenberg, Jack D.	University of New Brunswick
Gegenberg, Thea	University of Waterloo
Golovko, Roman	University of Southern California
Gross, Mark W.	University of California, San Diego
Gunturkun, Mustafa Hakan	University of Oregon
Häbich, Mathias	Johann Wolfgang Goethe-Universität Frankfurt
Hampton, Marshall	University of Minnesota
Haque, Mohammad Moinul	University of Texas
Harris, Kelley	University of California

Name	Institution
Hering, Milena	University of Connecticut
Herold, Matthias	TU Kaiserslautern
Ho, Chung-I	University of Minnesota Twin Cities
Hsiao, Jen-Chieh	Purdue University
HUANG, Yi	Georgia Institute of Technology
Itenberg, Ilia	Institut de Recherche Mathématique Avancée de Strasbourg
Izhakian, Zur	Bar-Ilan University
Jensen, Anders Nedergaard	Georg-August-Universität zu Göttingen
Jeronimo, Gabriela Talí	University of Buenos Aires
Johansson, Petter	The Mathematical Sciences Research Institute
Johns, Joseph Amos	Columbia University
Juhl-Jöricke, Burglind Elisabeth Jutta	Institut des Hautes Études Scientifiques (IHES)
Kang, Ning	University of Texas
Karaali, Gizem	Pomona College
Karshon, Yael	University of Toronto
Kedzierska, Anna Magdalena	University of California
Kong, Nayeong	Pusan National University
Kutluhan, Cagatay	University of Michigan
Lagerberg, Aron Freyr	Aron Lagerberg
Lakhani, Chirag Manmohan	North Carolina State University
Lawrence, Albert	
Levin, Brandon	Stanford University
Leykin, Anton	Georgia Institute of Technology
Liu, Chiu-Chu (Melissa)	Columbia University
Lopez de Medrano, Lucia	National Autonomous University of Mexico (UNAM)
Lundqvist, Johannes	University of Stockholm
Maclagan, Diane	University of Warwick
Manon, Christopher	University of California
Marciniak, Malgorzata Aneta	University of Missouri
Markwig, Hannah	Georg-August-Universität zu Göttingen
Markwig, Thomas Ewald	Mathematisches Institut, Georg-August-Universität Göttingen
McCrory, Clinton Graydon	University of Georgia
Meyer, Henning	University of Kaiserslautern, Department of Mathematics
Mikhalkin, Grigory	Université de Genève
Miranda, Eric Douglas	San Francisco State University
Mondragon, Damien Joseph	University of California
Munguia, Erendira	National Autonomous University of Mexico (UNAM)
Musiker, Gregg	MIT, Department of Mathematics
Nairn, Kristen Ann	St. John's University
Nesci, Michele	Université de Genève
Nill, Benjamin Thorsten	Mathematical Institute, Freie Universitaet Berlin
Nilsson, Lisa Maria	Stockholm University
Nisse, Mounir	Université de Paris VI (Pierre et Marie Curie)
Novoseltsev, Andrey	University of Alberta
Obama-Prevost, Darryl Reynard	CHEIKH ANTA DIOP INTERNATIONAL ACADEMIES & INSTITUTES
Ochse, Dennis	Universität Kaiserslautern
OSullivan, Michael	San Diego State University
Ovchinnikov, Sergei	San Francisco State University
Pal, Suchandan	University of Florida
Passare, Mikael	University of Stockholm
Pate, Kevin Jang	Oakland University
Rezazadegan, Reza	Rutgers University
Rincon, Felipe	University of California
Risler, Jean-Jacques	Université de Paris VI (Pierre et Marie Curie)
Rowen, Louis	Bar-Ilan University
Rutgayzer, Margarita	Humboldt-Universität
Rydh, David	University of California
Salur, Sema	Northwestern University
Sanyal, Raman	University of California
Sanyal, Soumya Deepta	University of Missouri

Name	Institution
Schmitz, Kirsten	Universitaet Osnabrueck
Schroeter, Franziska	Georg-August-Universität zu Göttingen
Seceleanu, Alexandra	University of Illinois at Urbana-Champaign
Severs, Christopher	Arizona State University
Shaker, Hani	COMSATS Institute of Information Technology, Lahore, Pakistan.
Shaw, Kristin Marie	University of Toronto
Shiu, Anne J.	University of California
Sottile, Frank	Texas A & M University
Stapledon, Alan Michael	University of Michigan
Sturmfels, Bernd	UCB - University of California, Berkeley
Tabera, Luis Felipe	University of California
Talaska, Kelli	University of Michigan
Taliwal, Vikas	Cornell University
Tevelev, Evgueni	University of Massachusetts
Torchiani, Carolin	Technical University of Kaiserslautern
vaccarino, francesco	
Vinzant, Cynthia	University of California
Viray, Bianca	University of California
Viro, Oleg	SUNY
Walker, Björn	
Werner, Annette	Johann Wolfgang Goethe-Universität Frankfurt
Williams, Lauren	University of California
Wong Kew, Rich	Presidential Postdoctoral Fellows and Research Scientists
Wu, Weiwei	University of Minnesota Twin Cities
Wulcan, Elizabeth	Department of Mathematics, University of Michigan
Yu, Josephine T.	Massachusetts Institute of Technology
Yun, Taedong	Massachusetts Institute of Technology

Introductory Workshop: Tropical Geometry
Held: August 24-28, 2009
The Mathematical Sciences Research Institute

Officially Registered Participant Information
140 participants

Gender (n = 140participants)		
Male	66.13%	82
Female	32.26%	40
Declined to state	1.61%	2

Ethnicity (n =83 participants)		
White	59.04%	49
Asian	16.87%	14
Hispanic	3.61%	3
Pacific Islander	0.00%	0
Black	2.41%	2
Native American	2.41%	2
Declined to state	15.66%	13

Report on the MSRI Workshop: Tropical Geometry in Combinatorics and Algebra

Federico Ardila (San Francisco State University)
David E Speyer (MIT)
Jenia Tevelev (UMass Amherst)
Lauren Williams (Harvard)

1 Introduction

The oldest use of tropical methods, and the origins of the term "tropical" itself, come from combinatorial optimization theory. For example, let M be the square matrix expressing distances in a graph. Then $M \odot M$, where the product is taken tropically, gives the shortest two-step path between any two points. Similarly, the sum $1 \oplus M \oplus M \odot M \oplus \cdots$ gives the shortest route between any two points. This sort of algebraic manipulation of tropical objects, in the solution of combinatorial problems, played an important role in the early history of tropical mathematics.

The recent growth in tropical work comes from a very different direction. Grigory Mikhalkin, following an idea of Kapranov, has shown how to use tropical methods to compute Gromov-Witten invariants. This development of tropical methods has come from the community of geometers and mathematical physicists, and the resulting mathematics has a more visual and geometric style.

Our workshop focused on researchers who are bringing these new methods into algebraic geometry and number theory, and back into combinatorics. This has involved finding foundations which are more algebraic, such as substituting non-Archimedean analysis for degeneration of complex structure; and finding methods which are more computational, such as using Gröbner bases in place of the space of all valuations. A frequent theme of conversations, in the lecture hall and at tea, was how to take sophisticated tools and make them computationally effective.

All lectures were recorded, both by video camera and by a designated note-taker, and are available to the public on the MSRI website; so that they may cointinue to serve as a valuable reference.

2 Summary of lectures

Our first lecture, delivered by Sam Payne, described how to set up the formalism of tropical geometry to connect cleanly with tools from non-Archimedean analysis. The clarity of Payne's lecture was helpful both for students who were entering the field and for the diverse experts who needed to communicate with each other. Payne concentrated on applications of tropical methods to studying the topology of algebraic varieties. His talk echoed a common theme of the week: Tropical methods are powerful tools for computing topology yet, at the same time, a full understanding requires combining tropical ideas with other sophisticated tools.[1]

There were three other lectures which discussed the use of tropical methods in classical geometry: Diane Maclagan's talk on the ample cone of $\overline{M}_{0,n}$ and other classical spaces; Alexander Esterov's lecture on discriminants and related objects and Eric Katz's presentation on constructing curves inside algebraic varieties. These talks displayed both the power of tropical techniques, and the need to use them in combination with other tools from algebraic geometry.

As already mentioned, the recent interest in tropical techniques was sparked by the success of tropical methods in studying questions about algebraic curves. The subject of algebraic curves is famous for the numerous perspectives from which its objects can be analyzed, including complex analysis, hyperbolic geometry, algebra and graph theory. Many of our speakers discussed how to combine the tropical methods with a combinatorial perspective; these speakers included Matt Baker, Filip Cools, Hannah Markwig, Filippo Vivianni, and Josephine Yu. Grigory Mikhalkin and Danielle Allesandrini represented the geometric schools. The theory of tropical curves is solidifying; the experts now agree on what the basic definitions and concepts of the theory should look like and are focusing on applying their understanding. The lectures on tropical curves from these many viewpoints should be very useful to students coming into this field now and in the future.

Tropical geometry makes fundamental use of non-Archimedean valued fields; usually considered a tool of number theory. Two of our speakers described how they had returned the favor by providing number theorists with tropical tools. Walter Gubler spoke about his recent success in using tropical methods to complete the proof of the Bogomolov conjecture in a certain setting.[2] Gubler explained that his proof involves constructing certain measures on tropical varieties; which should in some sense be analogous to the Chow forms that had been used in other settings. The effort to understand these measures occupied much of the conversation after Gubler's talk; and the next day Matthew Baker explained how these measures were related to concepts that were previously known in electrical network theory. In a more speculative vein, Annette Werner spoke on the early stages of a project to use tropical geometry to understand buildings; which are important in the representation theory of p-adic groups.

Throughout the week, there was an ongoing conversation between number theorists, who were very familiar with the abstract techniques of rigid geometry, and computational algebraic geometers, who wanted to make these abstract

[1] In this case, the relevant tool was Deligne's theory of weight filtrations.

[2] Specifically, he proved the theorem for abelian varieties over function fields, when there is some prime of the function field for which the abelian variety has completely multiplicative reduction.

methods concrete. Representatives of the latter school included Bernd Strumfels, Thomas Markwig and Diane Maclagan. On Wednesday afternoon, when no talks were scheduled, the number theorists and the computationalists spent the entire afternoon discussing how computer algebra could aid, and be aided by, the number theoretic perspective.

Finally, our conference had numerous attendees, and several representatives, from the field of combinatorics. The most inspiring talk of the conference was Sergey Fomin's presentation. He challenged combinatorialists to find a combinatorial structure underlying Gromov-Witten theory, in the same way that tableaux combinatorics underlies the intersection theory of homogenous spaces. Fomin has begun such a project. Working together with Mikhalkin, his methods have already lead to a proof of a conjecture of Göttsche. The more exciting aspect of his work, however, is the new problems it suggests. His numerical data suggests some relationship between genus zero Gromov-Witten invariants and the combinatorics of parking functions, the details of which are completely unclear.

A similarly broad talk was given by Arkady Berenstein, who surveyed the use of tropical methods in combinatorial representation theory. This very demanding talk laid out a general description of the ways in which lattice points on tropical varieties have been used to describe representations of Lie groups. The talk was striking not only for the large picture it presented, but also for the many parts of the picture that were still mysterious. Berenstein's talk was followed up shortly thereafter by a presentation by Gleb Koshevoy, who described his success at filling in a part of Berenstein's picture by solving a conjecture of Leclerc and Zelevinsky.

Polyhedral combinatorics was a frequent theme, due to the polyhedral nature of tropical objects. Alex Fink explained how to relate tropical intersection theory to McMullen's polytope algebra, connecting recent tropical developments with classic polyhedral techniques. Michael Joswig and Thorsten Theobald also spoke specifically about polyhedral ideas, and polyhedral geometry played a major role in some of the speakers already mentioned above, such as Esterov, Markwig and Yu.

Tropical Geometry in Combinatorics and Algebra

Invited Speakers

Alessandrini, Daniele	Université de Strasbourg I (Louis Pasteur)
Baker, Matthew Howard	Georgia Institute of Technology
Berenstein, Arkady	University of Oregon
Caporaso, Lucia	Universita Roma TRE
Cools, Filip	Katholieke Universiteit Leuven
Esterov, Alex	Laboratoire J. A. Dieudonné
Fink, Alex	University of California
Fomin, Sergey	University of Michigan
Gubler, Walter	Institute for Advanced Study
Joswig, Michael	TU Berlin
Katz, Eric Edward	University of Texas
Koshevoy, Gleb	Russian Academy of Sciences
Markwig, Hannah	Georg-August-Universität zu Göttingen
Payne, Sam	Stanford University
Qu, Zhenhua	University of Texas
Theobald, Thorsten	Goethe-Universitaet Frankfurt, FB 12 - Mathematics
Werner, Annette	Johann Wolfgang Goethe-Universität Frankfurt
Yu, Josephine T.	Massachusetts Institute of Technology

MSRI Mathematical Sciences Research Institute

Tropical Geometry in Combinatorics and Algebra

October 12 to October 16, 2009

Monday October 12, 2009		
09:30AM - 10:30AM	Sam Payne	Topology of compactified tropicalizations
10:30AM - 11:00AM	Coffee, tea in the atrium	
11:00AM - 12:00PM	Alex Esterov	Newton polyhedra and Minkowski integrals.
12:00PM - 02:00PM	Lunch	
02:00PM - 03:00PM	Eric Katz	Realization Spaces for Tropical Varieties.
03:00PM - 03:30PM	Coffee, tea in atrium	
04:00PM - 05:00PM	MSRI-Evans lecture	
Tuesday October 13, 2009		
09:30AM - 10:30AM	Arkady Berenstein	Geometric crystals and tropical combinatorics
10:30AM - 11:00AM	Coffee, tea in the atrium	
11:00AM - 12:00PM	Gleb Koshevoy	Bases of tropical Plucker functions, wirings, tilings and Leclerc-Zelevinsky conjectures.
12:00PM - 02:00PM	Lunch	
02:00PM - 03:00PM	Filip Cools	Tropical geometry and dissimilarity vectors of trees
03:00PM - 04:00PM	Coffee, tea in atrium	
04:00PM - 05:00PM	Daniele Alessandrini	Tropicalization of Teichmuller spaces
Wednesday October 14, 2009		
09:00AM - 10:00AM	Walter Gubler	Tropical analytic geometry and the Bogomolov conjecture
10:00AM - 10:30AM	Coffee, tea in the atrium	
10:30AM - 11:30AM	Josephine Yu	Linear Systems on Tropical Curves
11:45AM - 12:45PM	Diane Maclagan	Tropical bounds on effective cycles.
Thursday October 15, 2009		
09:30AM - 10:30AM	Matthew Baker	Metric properties of the tropical Abel-Jacobi map
10:30AM - 11:00AM	Coffee, tea in the atrium	
11:00AM - 12:00PM	Filippo Viviani	On the tropical Torelli map
12:00PM - 02:00PM	Lunch	
02:00PM - 03:00PM	Sergey Fomin	Enumeration of plane curves and labeled floor diagrams
03:00PM - 03:30PM	Coffee, tea in the atrium	
04:00PM - 05:00PM	Hannah Markwig	Berkeley Colloquium
Friday October 16, 2009		
09:30AM - 10:30AM	Michael Joswig	"Coarse tropical convexity and cellular resolutions"
10:30AM - 11:00AM	Coffee, tea in the atrium	
11:00AM - 12:00PM	Thorsten Theobald	Combinatorics and genus of tropical intersections and Ehrhart theory
12:00PM - 02:00PM	Lunch	
02:00PM - 03:00PM	Alex Fink	"Tropical cycles and Chow polytopes"
03:00PM - 04:00PM	Coffee, tea in the atrium	
04:00PM - 05:30PM	Annette Werner	Buildings and tropical geometry

Currently Available Videos

- **Sam Payne** , Topology of compactified tropicalizations *October 12,2009, 09:30 AM to 10:30 AM*
- **Alex Esterov** , Newton polyhedra and Minkowski integrals. *October 12,2009, 11:00 AM to 12:00 PM*
- **Eric Katz** , Realization Spaces for Tropical Varieties *October 12,2009, 02:00 PM to 03:00 PM*
- **Arkady Berenstein** , Geometric crystals and tropical combinatorics *October 13,2009, 09:30 AM to 10:30 AM*
- **Gleb Koshevoy** , Bases of tropical Plucker functions, wirings, tilings and Leclerc-Zelevinsky conjectures. *October 13,2009, 11:00 AM to 12:00 PM*
- **Filip Cools** , Tropical geometry and dissimilarity vectors of trees *October 13,2009, 02:00 PM to 03:00 PM*
- **Daniele Alessandrini** , Tropicalization of Teichmuller spaces *October 13,2009, 04:00 PM to 05:00 PM*
- **Walter Gubler** , Tropical analytic geometry and the Bogomolov conjecture *October 14,2009, 09:00 AM to 10:00 AM*
- **Josephine Yu** , Linear Systems on Tropical Curves *October 14,2009, 10:30 AM to 11:30 AM*
- **Diane Maclagan** , Tropical bounds on effective cycles *October 14,2009, 11:45 AM to 12:45 PM*
- **Matthew Baker** , Metric properties of the tropical Abel-Jacobi map *October 15,2009, 09:30 AM to 10:30 AM*
- **Filippo Viviani** , On the tropical Torelli map *October 15,2009, 11:00 AM to 12:00 PM*
- **Sergey Fomin** , Enumeration of plane curves and labeled floor diagrams *October 15,2009, 02:00 PM to 03:00 PM*
- **Michael Joswig** , Coarse tropical convexity and cellular resolutions *October 16,2009, 09:30 AM to 10:30 AM*
- **Michael Joswig** , Brief Software Tutorial *October 16,2009, 10:30 AM to 11:00 AM*
- **Thorsten Theobald** , Combinatorics and genus of tropical intersections and Ehrhart theory *October 16,2009, 11:00 AM to 12:00 PM*
- **Alex Fink** , Tropical cycles and Chow polytopes *October 16,2009, 02:00 PM to 03:00 PM*
- **Annette Werner** , Buildings and tropical geometry *October 16,2009, 04:00 PM to 05:00 PM*You can find videos of other workshops and events on our VMath - Streaming Video page.

Participant List

MSRI Workshop:

Tropical Geometry in Combinatorics and Algebra

October 12-16, 2009

at Mathematical Sciences Research Institute, Berkeley California

Name	Institution
Ahmad, Umair	Lahore University of Management Sciences
Alessandrini, Daniele	Université de Strasbourg I (Louis Pasteur)
Allermann, Lars	TU Kaiserslautern, FB Mathematik
Amini, Omid	École Normale Supérieure
Andreas, Jillianne Joy	Indiana University
Ardila, Federico	San Francisco State University
Aroca, Fuensanta	National Autonomous University of Mexico (UNAM)
Baker, Matthew Howard	Georgia Institute of Technology
Berenstein, Arkady	University of Oregon
Blanco, Saul	Cornell University
Block, Florian	University of Michigan
Bogart, Tristram	University of Washington
Brodsky, Sarah	University of California
Caporaso, Lucia	Universita Roma TRE
Chan, Melody	University of California
Chen, Chen-wei	National Cheng Chi University
Christensen, Chris	TU Dortmund / Fakultät für Mathematik
Cools, Filip	Katholieke Universiteit Leuven
Cruickshank, James	National University of Ireland, Galway
Cueto, Maria Angelica	University of California
Devadoss, Satyan Linus	Williams College
Dickenstein, Alicia M.	University of Buenos Aires
Diemer, Colin	University of Pennsylvania
Dochtermann, Anton Michael	TU Berlin
Erman, Daniel Max	University of California
Escobar, Laura	San Francisco State University
Esterov, Alex	Laboratoire J. A. Dieudonné
Falk, Michael J.	Northern Arizona University
Feichtner, Eva Maria	Universität Bremen
Fink, Alex	University of California
Fomin, Sergey	University of Michigan
Garay, Cristhian Emmanuel	Institut Mathematiques de Jussieu
Gathmann, Andreas	University of Kaiserslautern
Gubler, Walter	Institute for Advanced Study
Gunturkun, Mustafa Hakan	University of Oregon
Ha, Tai Huy	Tulane University
Haas, Ruth	Smith College
Haase, Christian Alexander	Math Dept, FU Berlin
Haque, Mohammad Moinul	University of Texas
Helminck, Aloysius Gerardus	North Carolina State University
Hept, Kerstin Verena Sonja	Johann Wolfgang Goethe-Universität Frankfurt
Hering, Milena	University of Connecticut
Herold, Matthias	TU Kaiserslautern
Hower, Valerie	University of California
Hsiao, Jen-Chieh	Purdue University
Hyeon, Donghoon	Pohang University of Science and Technology (POSTECH)
Itenberg, Ilia	Institut de Recherche Mathématique Avancée de Strasbourg
Izhakian, Zur	Bar-Ilan University
Jensen, Anders Nedergaard	Georg-August-Universität zu Göttingen
Johansson, Petter	The Mathematical Sciences Research Institute
Joswig, Michael	TU Berlin
Karaali, Gizem	Pomona College
Katz, Eric Edward	University of Texas

Name	Institution
Kharlamov, Viatcheslav M.	Universite de Strasbourg, IRMA
Kim, Jin-Hong	KAIST
Koshevoy, Gleb	Russian Academy of Sciences
Lam, Cario	University of California
Lenz, Matthias	TU Berlin
Leon, Emerson	TU Berlin
Leykin, Anton	Georgia Institute of Technology
Lopez de Medrano, Lucia	National Autonomous University of Mexico (UNAM)
Lopez de Medrano, Santiago	UNAM - Universidad Nacional Autonoma de Mexico
Lukyanenko, Inna	TU Berlin
Lundqvist, Johannes	University of Stockholm
Maclagan, Diane	University of Warwick
Maeno, Toshiaki	Kyoto University
Markwig, Hannah	Georg-August-Universität zu Göttingen
Markwig, Thomas Ewald	Mathematisches Institut, Georg-August-Universität Göttingen
Meyer, Henning	Universität Kaiserslautern
Miranda, Eric Douglas	San Francisco State University
Morales, Alejandro	Massachusetts Institute of Technology
Musiker, Gregg	MIT, Department of Mathematics
Nairn, Kristen Ann	St. John's University
Nesci, Michele	Université de Genève
Nill, Benjamin Thorsten	Mathematical Institute, Freie Universitaet Berlin
Nisse, Mounir	Université de Paris VI (Pierre et Marie Curie)
Ochse, Dennis	Universität Kaiserslautern
Paquet, Agnes	Monogram Biosciences
Passare, Mikael	University of Stockholm
Pate, Kevin Jang	Oakland University
Payne, Sam	Stanford University
Qu, Zhenhua	University of Texas
Rabinoff, Joe David	Harvard University
Rincon, Felipe	University of California
Rowen, Louis	Bar-Ilan University
SAGLAM, Nur Kadriye	Middle East Technical University (ODTU)
Sanyal, Raman	University of California
Schmitz, Kirsten	Universitaet Osnabrueck
Schroeter, Franziska	Georg-August-Universität zu Göttingen
Severs, Christopher	Arizona State University
Shaw, Kristin Marie	University of Toronto
Shiu, Anne J.	University of California
Skoldberg, Emil	National University of Ireland, Galway
Speyer, David	Massachusetts Institute of Technology
Stapledon, Alan Michael	University of Michigan
Sturmfels, Bernd	UCB - University of California, Berkeley
Tabera, Luis Felipe	University of California
Talaska, Kelli	University of Michigan
Taliwal, Vikas	Cornell University
Tevelev, Evgueni	University of Massachusetts
Theobald, Thorsten	Goethe-Universitaet Frankfurt, FB 12 - Mathematics
Torchiani, Carolin	Technical University of Kaiserslautern
Verschelde, Jan	University of Illinois at Chicago
Vinzant, Cynthia	University of California
Viviani, Filippo	Terza Università di Roma
Vorwerk, Kathrin	Royal Institute of Technology (KTH)
Wagner, Till	Johann Wolfgang Goethe-Universität Frankfurt
Walker, Björn	
Wang, Haining	Pennsylvania State University
Werner, Annette	Johann Wolfgang Goethe-Universität Frankfurt
White, Jacob Anthony	Arizona State University
Williams, Lauren Kiyomi	Harvard University
Williams, Virginia Vassilevska	University of California

Name	Institution
Wong Kew, Rich	**Presidential Postdoctoral Fellows and Research Scientists**
Yu, Josephine T.	**Massachusetts Institute of Technology**
ZABUN, Arzu Remziye	**Middle East Technical University (ODTU)**
Severs, Christopher	Arizona State University
Shaker, Hani	COMSATS Institute of Information Technology, Lahore, Pakistan.
Shaw, Kristin Marie	University of Toronto
Shiu, Anne J.	University of California
Sottile, Frank	Texas A & M University
Stapledon, Alan Michael	University of Michigan
Sturmfels, Bernd	UCB - University of California, Berkeley
Tabera, Luis Felipe	University of California
Talaska, Kelli	University of Michigan
Taliwal, Vikas	Cornell University
Tevelev, Evgueni	University of Massachusetts
Torchiani, Carolin	Technical University of Kaiserslautern
vaccarino, francesco	
Vinzant, Cynthia	University of California
Viray, Bianca	University of California
Viro, Oleg	SUNY
Walker, Björn	
Werner, Annette	Johann Wolfgang Goethe-Universität Frankfurt
Williams, Lauren	University of California
Wong Kew, Rich	Presidential Postdoctoral Fellows and Research Scientists
Wu, Weiwei	University of Minnesota Twin Cities
Wulcan, Elizabeth	Department of Mathematics, University of Michigan
Yu, Josephine T.	Massachusetts Institute of Technology
Yun, Taedong	Massachusetts Institute of Technology

Tropical Geometry in Combinatorics and Algebra
Held: October 12-16, 2009
The Mathematical Sciences Research Institute

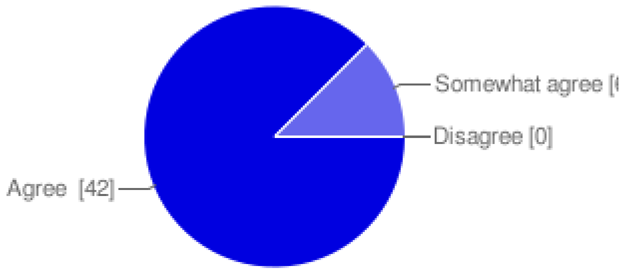
Officially Registered Participant Information
120 participants

Gender (n = 101participants)		
Male	85.00%	68
Female	13.75%	11
Declined to state	1.25%	1

Ethnicity (n =72 participants)		
White	58.33%	42
Asian	30.56%	22
Hispanic	1.39%	1
Pacific Islander	0.00%	0
Black	0.00%	0
Native American	0.00%	0
Declined to state	9.72%	7

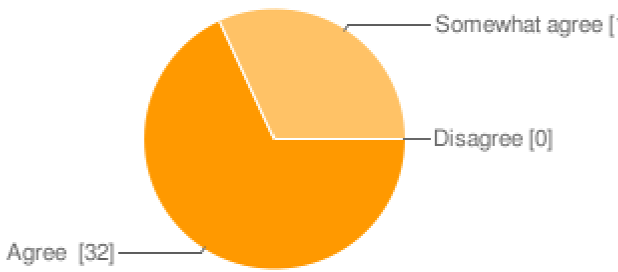
Tropical Geometry in Combinatorics and Algebra Summary See complete responses

Did the Various topics within the workshop integrate into a coherent picture?



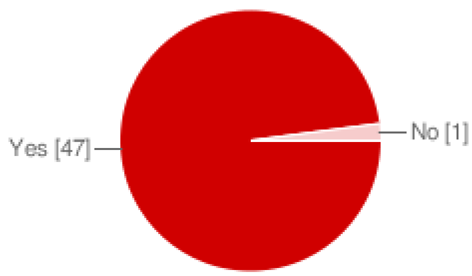
Agree	42	88%
Somewhat agree	6	13%
Disagree	0	0%

Was your background adequate to access a reasonable portion of the material?



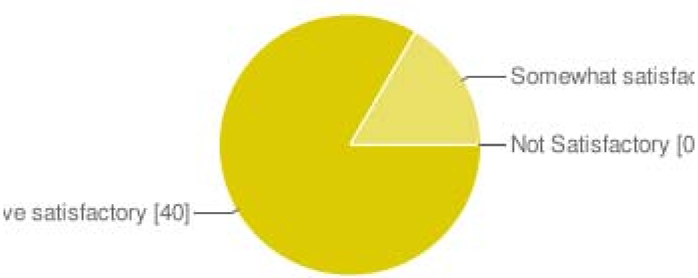
Agree	32	68%
Somewhat agree	15	32%
Disagree	0	0%

Did the workshop increase your interest in the subject?



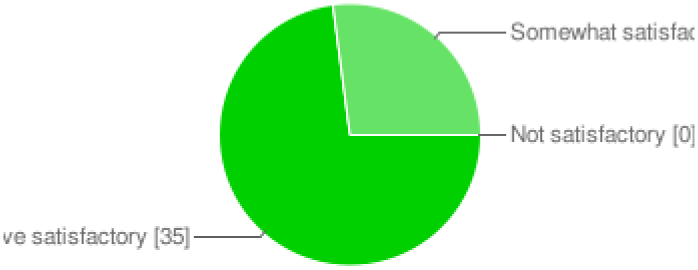
Yes	47	98%
No	1	2%

Was there adequate time between lectures for discussion?



Above satisfactory	40	83%
Somewhat satisfactory	8	17%
Not Satisfactory	0	0%

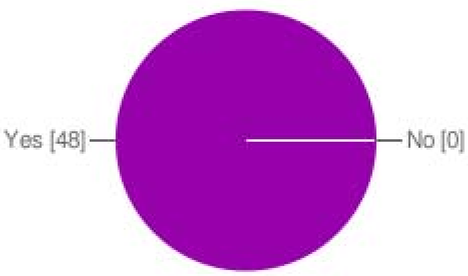
Were the speakers generally clear and well organized in their presentation?



Above satisfactory	35	73%
Somewhat satisfactory	13	27%
Not satisfactory	0	0%

Please explain
Fomin's talk and Joswig's talks were particularly good.The talks were very good for the most part.Overall very high quality of lectures and very good organisation before the workshop and throughout the week! MSRI provides very good infrastructure.This varied a lot from speaker to speaker.I would've enjoyed having only two lectures on Wednesday. But otherwise, I thought the timing was great.The quality of the (presentation of the) talks somewhat varied, but on the whole the content was interesting.Many topics where nicely presented and the overlaps showed the important facts about the genera...

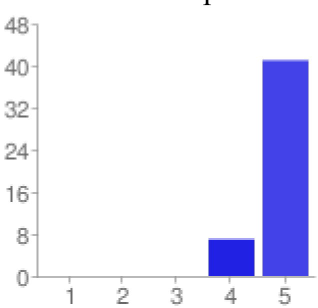
Was the workshop worth your time and effort?



Yes	48	100%
No	0	0%

Please explain
Very good mixture of topics, very interesting lectures, good speakers, altogether a fantastic workshopAs a researcher in tropical geometry, it was very useful to be able to talk to other people working in the field and discuss ideas.It was a great opportunity to broaden my perspective and to find other people, whose work in progress is related to my research, as well as to discuss my work in progress with experts.While some talks were not worth my time, mainly because of my insufficient knowledge in parts of the field, the MSRI managed to gather the world experts, making this the perfect pl...

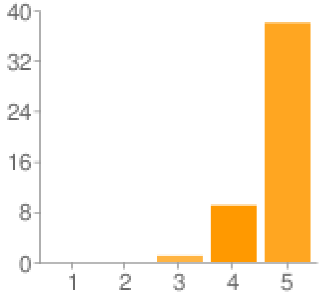
Your overall experience at MSRI



1 - Not satisfactory	0	0%
2	0	0%
3	0	0%
4	7	15%
5 - Above satisfactory	41	85%

Not satisfactory Above satisfactory

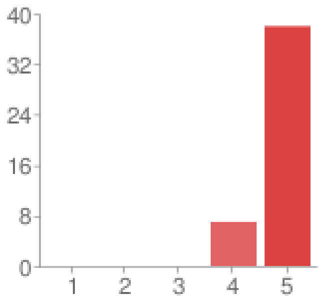
The assistance provided by the MSRI staff



1 - Not satisfactory	0	0%
2	0	0%
3	1	2%
4	9	19%
5 - Above satisfactory	38	79%

Not satisfactory Above satisfactory

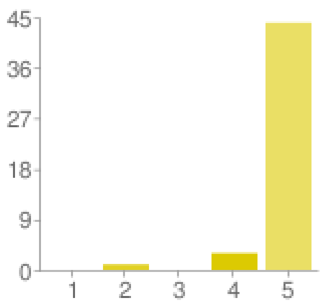
The overall atmosphere of MSRI



1 - Not satisfactory	0	0%
2	0	0%
3	0	0%
4	7	16%
5 - Above satisfactory	38	84%

Not satisfactory Above satisfactory

The physical surroundings



1 - Not satisfactory	0	0%
2	1	2%
3	0	0%
4	3	6%
5 - Above satisfactory	44	92%

Not satisfactory Above satisfactory

Thank you for completing this survey. We welcome any additional comments or suggestions you may have to improve the overall experience for future participants.

The heating in the lecture room is sometimes too hot. MSRI is a unique place to do research in math and to learn about the research of others. It was my third visit, and it was surely worth it, as twice before.MSRI manages to gather all leading scientist on a topic, thus establishing outstanding conferences. It is perfect as it is. There were no problems with any organizational issues for me and the place is really awesome.More extensive maps should be provided. In particular, there should be detailed walking maps of the MSRI vicinity, since the main difficulty at MSRI is getting up and d...

Tropical structures in geometry and physics
Nov 29-Dec 4, 2009
workshop report
Organizers: M. Gross, K. Hori, R. Kenyon, V. Kharlamov

One of the successes of tropical geometry is in its applications to different areas of recently developing mathematics. Among these are enumerative geometry, symplectic field theory, mirror symmetry, dimer models/random surfaces, amoebas and algas, instantons, cluster varieties, and tropical compactifications.

We invited a diverse crowd of mathematicians and physicists whose work was united by the fact that it uses tropical geometric methods. We feel that the workshop was highly successful in allowing these different communities to interact and explain their research to each other. Because of these differences in background the speakers had to make a special effort—with varied success—to explain the motivations and terminology of their research. The MSRI setting: library, meeting rooms, and relative isolation lent itself very well to developing collaborations.

The following general themes summarize the main ideas at the conference:

1. Applications of tropical geometry to mirror symmetry.
2. Connections between tropical geometry and real geometry.
3. Connections with combinatorics.
4. Connections between tropical geometry and string theory

Tropical applications to mirror symmetry were reflected in talks of Zharkov, Markwig, Abouzaid, Hacking, Boehm and Parker. Tropical structures arise naturally in mirror symmetry, since near large complex structure limit points in complex moduli space, holomorphic structures are expected to converge to tropical structures.

Zharkov considered the mirror statement, exploring how tropical curves ((p,q)-webs in string theoretic terminology) are related to Lagrangian submanifolds on the mirror.

Markwig discussed her joint work with Johannes Rau on tropical gravitational descendent Gromov-Witten invariants. She demonstrated that one can give a purely synthetic computation of descendent invariants by defining psi classes as tropical cycles on the moduli space of tropical curves in projective two-space, and then carrying out tropical intersection theory to obtain descendent invariants. She then showed these coincide with genuine holomorphic descendent Gromov-Witten invariants. Markwig and Shustin lanched a collaboration on tropicalization of families of curves with deep singularities.

Abouzaid, in joint work Mark Gross and Bernd Siebert, discussed recent ideas of using tropical geometry to analyze part of the Fukaya category; again, one considers limiting behaviour of holomorphic objects, in this case the holomorphic disks which arise in Floer theory.

Hacking, in joint work with Mark Gross and Sean Keel, applied tropical geometry to construct mirrors of rational surfaces with anti-canonical cycles of rational curves. As an application, he explained how this proved a 30 year old conjecture of Looijenga on the smoothability of cusp singularities.

Boehm discussed his work on constructing mirror pairs of Calabi-Yau manifolds using tropical geometry, coupled with Gröbner basis techniques. This work provides a generalization of the classical Batyrev-Borisov construction for complete intersections in toric varieties to other examples, such as Pfaffian Calabi-Yau manifolds.

Parker has developed a program for constructing relative Gromov-Witten invariants which is a vast generalization of the Li-Ruan construction of Gromov-Witten invariants relative a single divisor. This method uses tropical geometry to a certain extent, again in the context of a limiting picture for the constructions.

The talk by Passare attracted attention to various new aspects of the complex geometry of coamoebas that can be useful, for example, for developing a complexification of tropical geometry. It has stimulated joint works with J.-J.Risler and M.Nisse. An interesting idea for such a complexification was proposed by O.Viro. It attracted a wide interest and many discussions with many of the participants (Itenberg, Mikhalkin, Parker, Passare, and Zarkov, for example). After a talk by Parker, Viro and Kharlamov discussed with him relations between Parker's exploded manifolds and Viro's complex tropical geometry. They are actively continuing this collaboration.

Rares Rasdeaconu announced in his talk several new results obtained together with J. Solomon in the direction of constructing relative open Gromow-Witten invariants. Such invariants would open new ways in development of real enumerative geometry, for example. It was followed by discussions with Ionel, Itenberg, Kharlamov, Shustin.

As another interesting talk with fresh results was the talk by I.Zarkov who presented the current state of his collaboration with I.Itenberg, L.Katzarkov, and G.Mikhalkin on tropical Hodge theory.

Talks by Knutson, Speyer and Williams illustrated the uses of tropical methods in various combinatorics problems. Speyer and Kenyon discussed integrable structures arising in dimers and toric geometry; the connection with tropical geometry is not really clear yet. Williams and Kenyon began a discussion on the combinatorics of cluster algebras and dimer models.

Talks by Hanany, Krefl, Kol and Aganagic allowed to members of the program to become better aware of the approaches used in string theory by physicists in treating closely related objects and problems.

Research Workshop: Tropical Structures in Geometry and Physics
November 30 to December 4, 2009, MSRI, Berkeley, CA

Invited Speakers

lastname	firstname	institutionname
Abouzaid	Mohammed	MIT
Alessandrini	Daniele	Université de Strasbourg I (Louis Pasteur)
Boehm	Janko	Universitaet des Saarlandes, Campus E2 4
Brugalle	Erwan	Université Pierre et Marie Curie (Paris 6)
Hacking	Paul	University of Massachusetts
Hanany	Amihay	Imperial College London
Knutson	Allen	University of California, San Diego
Kol	Barak	Hebrew University
Krefl	Daniel	University of Tokyo
Litvinov	Grigory	Independent University of Moscow
Markwig	Hannah	Georg-August-Universität zu Göttingen
Parker	Brett	University of California
Passare	Mikael	University of Stockholm
Rasdeaconu	Rares	Hebrew University
Shustin	Eugenii	Tel Aviv University
Speyer	David	Massachusetts Institute of Technology
Tillmann	Stephan	University of Queensland
Tsikh	Avgust	Siberian Federal University
Williams	Lauren	University of California
Zharkov	Ilia	Kansas State University

Mathematical Sciences Research Institute

Tropical Structures in Geometry and Physics

November 30 to December 04

Monday November 30, 2009

09:00AM - 10:00AM	Allen Knutson	Reduced degenerations and Frobenius splitting
10:00AM - 11:00AM	Coffee, tea in the atrium	
11:00AM - 12:00PM	Lauren Williams	Teichmuller space, cluster algebras from surfaces, and the positivity conjecture
12:00PM - 01:30PM	Lunch	
01:30PM - 02:30PM	David Speyer	Determinental hypersurfaces, convex polynomials and tropical geometry
02:30PM - 03:00PM	Coffee, tea in the atrium	
03:00PM - 04:00PM	Mikael Passare	Some aspects of discriminantal (co)amoebas
04:15PM - 05:15PM	Oleg Viro	TBD
05:15PM - 06:30PM	Reception in the atrium	

Tuesday December 1, 2009

09:30AM - 10:30AM	Ilia Zharkov	Tropical (p,q)-classes of Lagrangian type
10:30AM - 11:00AM	Coffee, tea in the atrium	
11:00AM - 12:00PM	Eugenii Shustin	Real tropical enumerative invariants
12:00PM - 01:30PM	Lunch	
01:30PM - 02:30PM	Rares Rasdeaconu	Relative open Gromov-Witten invariants
02:30PM - 03:00PM	Coffee, tea in the atrium	
03:00PM - 04:00PM	Erwan Brugalle	Realizability of superabundant tropical curves
04:15PM - 05:15PM	Hannah Markwig	Tropical descendant Gromov-Witten invariants

Wednesday December 2, 2009

09:30AM - 10:30AM	Daniele Alessandrini	On the compactification of the parameter space of convex projective structures
10:30AM - 11:00AM	Coffee, tea in the atrium	
11:00AM - 12:00PM	Mohammed Abouzaid	TBD

Thursday December 3, 2009

09:30AM - 10:30AM	Daniel Krefl	Real enumerative geometry via the topological string
10:30AM - 11:00AM	Coffee, tea in the atrium	
11:00AM - 12:00PM	Amihay Hanany	(p,q) webs and their applications in string theory
12:00PM - 01:30PM	Lunch	
01:30PM - 02:30PM	Barak Kol	Tropical geometry and (p,q) webs
02:30PM - 03:00PM	Coffee, tea in the atrium	
03:00PM - 04:00PM	Mina Aganagic	Tropical Geometry and the Topological String
04:15PM - 05:15PM	Grigory Litvinov	Dequantization and tropical structures in classical mechanics and classical geometry

Friday December 4, 2009

09:30AM - 10:30AM	Stephan Tillmann	The Hilbert geometry of the n-simplex
10:30AM - 11:00AM	Coffee, tea in the atrium	
11:00AM - 12:00PM	Paul Hacking	Smoothing surface singularities via mirror symmetry
12:00PM - 01:30PM	Lunch	
01:30PM - 02:30PM	Janko Boehm	Calabi-Yau mirrors via tropical geometry
02:30PM - 03:00PM	Coffee, tea in the atrium	
03:00PM - 04:00PM	Brett Parker	Tropical curves and Gromov Witten invariants

Currently Available Videos

- **Sam Payne** , Topology of compactified tropicalizations *October 12,2009, 09:30 AM to 10:30 AM*
- **Alex Esterov** , Newton polyhedra and Minkowski integrals. *October 12,2009, 11:00 AM to 12:00 PM*
- **Eric Katz** , Realization Spaces for Tropical Varieties *October 12,2009, 02:00 PM to 03:00 PM*
- **Arkady Berenstein** , Geometric crystals and tropical combinatorics *October 13,2009, 09:30 AM to 10:30 AM*
- **Gleb Koshevoy** , Bases of tropical Plucker functions, wirings, tilings and Leclerc-Zelevinsky conjectures. *October 13,2009, 11:00 AM to 12:00 PM*
- **Filip Cools** , Tropical geometry and dissimilarity vectors of trees *October 13,2009, 02:00 PM to 03:00 PM*
- **Daniele Alessandrini** , Tropicalization of Teichmuller spaces *October 13,2009, 04:00 PM to 05:00 PM*
- **Walter Gubler** , Tropical analytic geometry and the Bogomolov conjecture *October 14,2009, 09:00 AM to 10:00 AM*
- **Josephine Yu** , Linear Systems on Tropical Curves *October 14,2009, 10:30 AM to 11:30 AM*
- **Diane Maclagan** , Tropical bounds on effective cycles *October 14,2009, 11:45 AM to 12:45 PM*
- **Matthew Baker** , Metric properties of the tropical Abel-Jacobi map *October 15,2009, 09:30 AM to 10:30 AM*
- **Filippo Viviani** , On the tropical Torelli map *October 15,2009, 11:00 AM to 12:00 PM*
- **Sergey Fomin** , Enumeration of plane curves and labeled floor diagrams *October 15,2009, 02:00 PM to 03:00 PM*
- **Michael Joswig** , Coarse tropical convexity and cellular resolutions *October 16,2009, 09:30 AM to 10:30 AM*
- **Michael Joswig** , Brief Software Tutorial *October 16,2009, 10:30 AM to 11:00 AM*
- **Thorsten Theobald** , Combinatorics and genus of tropical intersections and Ehrhart theory *October 16,2009, 11:00 AM to 12:00 PM*
- **Alex Fink** , Tropical cycles and Chow polytopes *October 16,2009, 02:00 PM to 03:00 PM*
- **Annette Werner** , Buildings and tropical geometry *October 16,2009, 04:00 PM to 05:00 PM*You can find videos of other workshops and events on our VMath - Streaming Video page.

Research Workshop: Tropical Structures in Geometry and Physics
November 30 to December 4, 2009, MSRI, Berkeley, CA

Officially Registered Participants

lastname	firstname	institutionname
Abouzaid	Mohammed	MIT
Alessandrini	Daniele	Université de Strasbourg I (Louis Pasteur)
Amini	Omid	École Normale Supérieure
Auroux	Denis	University of California
Beil	Charles	University of California
Block	Florian	University of Michigan
Boehm	Janko	Universitaet des Saarlandes, Campus E2 4
Brugalle	Erwan	Université Pierre et Marie Curie (Paris 6)
Budreau	Dan	University of California, San Diego
Castano-Bernard	Ricardo	Kansas State University
Chan	Kwok Wai	Harvard University
Cueto	Maria Angelica	University of California
Devadoss	Satyan	Williams College
Diaz	Rafael	Universidad del Rosario
Dickenstein	Alicia	University of Buenos Aires
Diemer	Colin	University of Pennsylvania
Eager	Richard	University of California
Early	Nicholas	Louisiana State University
Gadbled	Agnès	Université de Neuchatel - Institut de Mathématiques
Garay	Cristhian	Institut Mathematiques de Jussieu
Gathmann	Andreas	University of Kaiserslautern
Gross	Mark	University of California, San Diego
Haas	Ruth	Smith College
Hacking	Paul	University of Massachusetts
Hanany	Amihay	Imperial College London
Haque	Mohammad	University of Texas
Helminck	Aloysius	North Carolina State University
Herold	Matthias	TU Kaiserslautern
Hori	Kentaro	University of Toronto
Hower	Valerie	University of California
Ibrahim	Ashraf	Texas A & M University
Itenberg	Ilia	Institut de Recherche Mathématique Avancée de Strasbourg
Izhakian	Zur	Bar-Ilan University
Jensen	Anders	Georg-August-Universität zu Göttingen
Johansson	Petter	Stockholm University
Karaali	Gizem	Pomona College
Kenyon	Richard	Brown University
Knutson	Allen	University of California, San Diego
Kol	Barak	Hebrew University
Krefl	Daniel	University of Tokyo
Leung	Naichung	Chinese University of Hong Kong
Litvinov	Grigory	Independent University of Moscow
Lundqvist	Johannes	University of Stockholm
Madani	Farid	Université de Paris VI (Pierre et Marie Curie)
Markwig	Hannah	Georg-August-Universität zu Göttingen

Research Workshop: Tropical Structures in Geometry and Physics
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Matessi	Diego	Università del Piemonte Orientale ``Amedeo Avogadro''
McCrory	Clinton	University of Georgia
Meyer	Henning	Universität Kaiserslautern
Munguia	Erendira	National Autonomous University of Mexico (UNAM)
Musiker	Gregg	MIT, Department of Mathematics
Nairn	Kristen	St. John's University
Nesci	Michele	Université de Genève
Novoseltsev	Andrey	University of Alberta
Ochse	Dennis	Universität Kaiserslautern
Parker	Brett	University of California
Pascaleff	James	Massachusetts Institute of Technology
Passare	Mikael	University of Stockholm
Rasdeaconu	Rares	Hebrew University
Rowen	Louis	Bar-Ilan University
Schroeter	Franziska	Georg-August-Universität zu Göttingen
Severs	Christopher	Arizona State University
Shaw	Kristin	University of Toronto
Sheridan	Nicholas	Massachusetts Institute of Technology
Shustin	Eugenii	Tel Aviv University
Skoldberg	Emil	National University of Ireland, Galway
Slawinski	Mike	University of California
Speyer	David	Massachusetts Institute of Technology
Sverdlov	Roman	Raman Research Institute
Taliwal	Vikas	Cornell University
Thieullen	Philippe	Université de Bordeaux I
Tillmann	Stephan	University of Queensland
Torchiani	Carolin	Technical University of Kaiserslautern
Tsikh	Avgust	Siberian Federal University
Tyomkin	Ilya	Department of Mathematics, Ben Gurion University of the Negev
Venkatram	Kartik	Boston University
Werner	Annette	Johann Wolfgang Goethe-Universität Frankfurt
Williams	Lauren	University of California
Yu	Josephine	Massachusetts Institute of Technology
Zabun	Arzu	Middle East Technical University (ODTU)
Zharkov	Ilia	Kansas State University

Research Workshop: Tropical Structures in Geometry and Physics
November 30 to December 4, 2009, MSRI, Berkeley, CA

Officially Registered Participant Information

Participants		**80**

Gender		**80**
Male	76.25%	61
Female	20.00%	16
Declined to state	3.75%	3

Ethnicity*		**82**
White	69.51%	57
Asian	9.76%	8
Hispanic	7.32%	6
Pacific Islander	0.00%	0
Black	1.22%	1
Native American	0.00%	0
Declined to state	12.20%	10

* ethnicity specifications are not exclusive

Algebraic Structures in the Theory of Holomorphic Curves

November 16 to November 20, 2009

MSRI, Berkeley, CA, USA

Organizers:

Mohammed Abouzaid* (Clay Mathematics Institute)

Yakov Eliashberg (Stanford University)

Kenji Fukaya (Kyoto University)

Eleny Ionel (Stanford University)

Lenny Ng (Duke University)

Paul Seidel (MIT)

REPORT ON THE MSRI WORKSHOP: ALGEBRAIC STRUCTURES IN THE THEORY OF HOLOMORPHIC CURVES

Organizers.

- Mohammed Abouzaid* (Clay Mathematics Institute)
- Yakov Eliashberg (Stanford University)
- Kenji Fukaya (Kyoto University)
- Eleny Ionel (Stanford University)
- Lenny Ng (Duke University)
- Paul Seidel (MIT).

Modern symplectic topology arose in the early 1980's from a combination of different sources and techniques. This was soon followed by Gromov's introduction of holomorphic curves into the subject. These have now become the mainstream technique, both for questions internal to symplectic topology, and for interactions with other disciplines (such as enumerative geometry, through Gromov-Witten theory, and dynamics, through problems such as the the Weinstein and Arnold conjectures). Progress in these questions has become increasingly tied to an ever more sophisticated understanding of the algebraic structures which may be constructed from the moduli spaces of holomorphic curves. The workshop brought together experts on different aspects of these algebraic structures, and a fruitful discussion of ongoing and future developments took place during it.

There was a significant representation of several branches of symplectic topology, including Gromov-Witten theory, Symplectic Field Theory, and the study of Lagrangian Floer homology. Most of the lectures spanned more than one of these areas, providing an interesting forum for interactions among mathematicians working on similar problems using different techniques. In addition, connections with tropical geometry (the topic of the other MSRI program at the time) were explored.

Workshop Activities

The workshop started with a talk by Paolo Rossi, who was one of three MSRI postdocs giving lectures. He described the integrable systems which appear in symplectic field theory. These extend the well-studied topological recursion formulae in Gromov-Witten theory, whose connections with mirror symmetry formed the subject of Boris Dubrovin's talk. Gromov-Witten invariants conjecturally have additional structures beyond those of topological type: Alexander Givental gave a proof of the Virasoro conjecture for toric fibrations, while Xiaobo Liu explained a graph formalism for deriving universal equations on Gromov-Witten theory.

Several talks discussed approaches to computing Gromov-Witten invariants. Mark Gross presented an approach towards relative Gromov-Witten theory using log geometry, which would provide a bridge with tropical geometry, while Jun Li explained a new way of computing the genus 1 invariants for the quintic. Another family of examples arose from the quotient of simple spaces by Lie groups: Christopher Woodward focused on the closed sector, with the goal of computing the Gromov-Witten invariants of the quotient of a Lie group action, while Constantin Teleman discussed a formalism for taking the quotient of both the open and the closed sector of a field theory.

There were two more talks which took ideas from Gromov-Witten theory as their starting points: Soren Galatius explained a generalisation of the Mumford conjecture in the presence of a non-trivial target, and in which the source is allowed to be of dimension greater than 2, while Rahul Pandharipande described a counting invariant coming from Donaldson-Thomas theory which gives rise to the Homfly polynomial of knots.

Symplectic homology was a common theme for many of this workshop's talks. Kai Cieliebak presented connections between Rabinowitz Floer homology and symplectic homology, and used it to give obstructions on symplectic and contact embeddings. Frederic Bourgeois explained the isomorphism between contact homology and S^1-equivariant symplectic homology, which provides a bridge between symplectic field theory and Floer homology. This was particularly interesting in combination with the talk of Tobias Ekholm, who gave a surgery formula (joint with Bourgeois and Eliashberg) for various flavors of contact homology, which allows one to compute such invariants from a handle decomposition of a Stein manifold. During the semester, a working group at MSRI interested in symplectic field theory discussed a preliminary version of the results presented by Ekholm, and his talk included several applications, including the construction of an exotic symplectic $\mathbf{R}^6$, which in part arose out of conversations initiated in this working group. Janko Latschev explained a program for classifying prime 3-manifolds which admit Lagrangian embeddings in $\mathbf{C}^3$, by studying the algebraic structures supported by symplectic homology.

In the talk of Mohammed Abouzaid, symplectic homology was used to give a criterion which determines whether a collection of Lagrangians generate the Fukaya category. Our understanding of these categories has been greatly enhanced by the introduction of pseudo-holomorphic quilts. Sikimeti M'au explained how quilts allow one to understand the Fukaya category of a product in terms of the Fukaya categories of the factors. The open string analogue of symplectic homology also appeared in the talk of Maksim Maydanskiy, who used it to give a construct of exotic symplectic forms on the cotangent bundles of spheres. A more classical application of Lagrangian Floer homology was provided by Kaoru Ono, who proved the existence of a continuous family of Lagrangian tori in $S^2 \times S^2$ which are not Hamiltonian isotopic to each other, and which are all non-displaceable. Ono's talk used the theory developed by Fukaya, Oh, Ohta and Ono; Cheol-Huyn Cho provided in his lecture a series of constructions of homological invariants which one can extract from their theory.

The remaining talks on Lagrangian Floer homology focused on connections with mirror symmetry. Kenji Fukaya explained how to prove homological mirror symmetry for $K3$ surfaces by constructing the mirror as a moduli space of objects of the Fukaya category coming from the fibres of a Lagrangian torus fibration. Melissa Liu gave a proof of mirror symmetry for toric varieties and orbifolds using the correspondence between Lagrangians in the cotangent bundle of a torus and constructible sheaves on the base. Finally, Ivan Smith presented a new approach for using ideas from homological mirror symmetry to prove the faithfulness of the representation of the mapping class group into the symplectomorphism group of the representation variety.

Besides talks, the workshop presented an opportunity for numerous group discussions which were very productive and led to new collaborations. In particular, one such group discussed different approaches for understanding the precise relation between Weinstein handlebodies and symplectic Lefschetz fibrations. Conjecturally these two structures are equivalent, but at the moment the details remain to be worked out. The discussion of this problem at MSRI yielded new ideas which should be useful for addressing this question. A solution would be relevant for many applications.

The MSRI workshop was preceded a week earlier by a meeting at the American Institute of Mathematics (AIM), which was devoted specifically to the work of Bourgeois-Ekholm-Eliashberg and its ramifications. The two meetings were not conceived as continuations of each other; rather, the AIM workshop was more technical and specialized, while the MSRI workshop had a wider scope, with more diverse perspectives represented, and addressed itself to a broader audience. In our opinion, this was a successful combination which strengthened both workshops.

Algebraic Structures in the Theory of Holomorphic Curves

Invited Speakers

Boris Dubrovin	Advanced Studies
Cheol-Hyun Cho	Seoul National University
Chiu-Chu Liu	Columbia University
Christopher Woodward	Rutgers University
Dominic David Joyce	University of Oxford
Dusa Margaret McDuff	Barnard College
Frédéric Bourgeois	Université Libre de Bruxelles
Janko Latschev	Eidgenössische TH Zürich-Zentrum
Kai J. Cieliebak	München
Kaoru Ono	Hokkaido University
Katrin Wehrheim	Massachusetts Institute of Technology
Kevin Costello	University of Chicago
Mark McLean	University of Cambridge
Mark W. Gross	University of California, San Diego
Paolo Rossi	Institut Mathematiques de Jussieu
Sikimeti Luisa Ma'u	Massachusetts Institute of Technology
Tobias Ekholm	Uppsala University
Tom Coates	Harvard University

MSRI Mathematical Sciences Research Institute

Algebraic Structures in the Theory of Holomorphic Curves

November 16 - 20, 2009

Monday November 16, 2009		
09:15AM - 10:15AM	Paolo Rossi	Hamiltonian systems and topological recursion in SFT
10:30AM - 11:00AM	Coffee, tea in the atrium	
11:00AM - 12:00PM	Sikimeti Ma'u	Quilts and A-infinity structures
12:00PM - 01:15PM	Lunch	
01:15PM - 02:15PM	Soren Galatius	TBD
02:15PM - 02:30PM	Break	
02:30PM - 03:30PM	Boris Dubrovin	Integrable hierarchies of the topological type
03:30PM - 04:00PM	Coffee, tea in the atrium	
04:00PM - 05:00PM	Alexander Givental	On the Virasoro constraints for toric fibrations
Tuesday November 17, 2009		
09:30AM - 10:30AM	Tobias Ekholm	Legendrian contact homology and symplectic homology in dimension four
10:30AM - 11:00AM	Coffee, tea in the atrium	
11:00AM - 12:00PM	Christopher Woodward	Morphisms of CohFT's and the mirror map.
12:00PM - 01:15PM	Lunch	
01:15PM - 02:15PM	Kai Cieliebak	Some remarks on symplectic and contact homology
02:15PM - 02:30PM	Break	
02:30PM - 03:30PM	Frédéric Bourgeois	The Gysin exact sequence for S1-equivariant symplectic homology.
03:30PM - 04:00PM	Coffee, tea in the atrium	
04:00PM - 05:00PM	Janko Latschev	Symplectc homology and Lagrangian submanifolds of C^n
05:00PM - 06:00PM	Reception in the atrium	

Wednesday November 18, 2009		
09:00AM - 10:00AM	Katrin Wehrheim	Introduction to Polyfolds
10:15AM - 11:15AM	Maksim Maydanskiy	TBD
11:30AM - 12:30PM	Xiaobo Liu	Universal Equations for Gromov-Witten invariants
Thursday November 19, 2009		
09:30AM - 10:30AM	Kenji Fukaya	Lagrangian surgery and rigid analytic family of Floer homologies
10:30AM - 11:00AM	Coffee, tea in the atrium	
11:00AM - 12:00PM	Cheol-Hyun Cho	On the obstructed Lagrangian Floer theory
12:00PM - 01:15PM	Lunch	
01:15PM - 02:15PM	Kaoru Ono	Lagrangian Floer theory on symplectic resolutions of singular toric surfaces
02:15PM - 02:30PM	Break	
02:30PM - 03:30PM	Ivan Smith	Fukaya categories of pencils of quadrics
03:30PM - 04:00PM	Coffee, tea in the atrium	
04:00PM - 05:00PM	Berkeley Colloquium	
Friday November 20, 2009		
09:30AM - 10:30AM	Chiu-Chu Liu	Coherent-constructible correspondence and homological mirror symmetry for toric varieties and toric orbifolds
10:30AM - 11:00AM	Coffee, tea in the atrium	
11:00AM - 12:00PM	Rahul Pandharipande	Pairs, BPS states, and knot invariants.
12:00PM - 01:15PM	Lunch	
01:15PM - 02:15PM	Constantin Teleman	Gauged mirror symmetry and Landau-Ginzburg potentials in the Brauer group
02:15PM - 02:30PM	Break	
02:30PM - 03:30PM	Jun Li	Genus one GW-invariants of quintics revisited
03:30PM - 04:00PM	Coffee, tea in the atrium	
04:00PM - 05:00PM	Mark Gross	Log Gromov-Witten invariants

Currently Available Videos

- **Paolo Rossi** , Hamiltonian systems and topological recursion in SFT *November 16,2009, 09:15 AM to 10:15 AM*
- **Sikimeti Ma'u** , "Quilts and A-infinity structures" *November 16,2009, 11:00 AM to 12:00 PM*
- **Soren Galatius** , Monoids of moduli spaces of manifolds *November 16,2009, 01:15 PM to 02:15 PM*
- **Boris Dubrovin** , "Integrable hierarchies of the topological type" *November 16,2009, 02:30 PM to 03:30 PM*
- **Alexander Givental** , On the Virasoro constraints for toric fibrations *November 16,2009, 04:00 PM to 05:00 PM*
- **Tobias Ekholm** , Legendrian contact homology and symplectic homology in dimension four *November 17,2009, 09:30 AM to 10:30 AM*
- **Christopher Woodward** , Morphisms of CohFT's and the mirror map *November 17,2009, 11:00 AM to 12:00 PM*
- **Kai Cieliebak** , Some remarks on symplectic and contact homology *November 17,2009, 01:15 PM to 02:15 PM*
- **Frédéric Bourgeois** , The Gysin exact sequence for S1-equivariant symplectic homology *November 17,2009, 02:30 PM to 03:30 PM*
- **Janko Latschev** , Symplectc homology and Lagrangian submanifolds of C^n *November 17,2009, 04:00 PM to 05:00 PM*
- **Mohammed Abouzaid** , On generating Fukaya categories *November 18,2009, 09:00 AM to 10:00 AM*
- **Maksim Maydanskiy** , Exotic symplectic structures on cotangent bundles of spheres from the A_m singularity *November 18,2009, 10:15 AM to 11:15 AM*
- **Xiaobo Liu** , Universal Equations for Gromov-Witten invariants *November 18,2009, 11:30 AM to 12:30 PM*
- **Kenji Fukaya** , Lagrangian surgery and rigid analytic family of Floer homologies *November 19,2009, 09:30 AM to 10:30 AM*
- **Cheol-Hyun Cho** , On the obstructed Lagrangian Floer theory *November 19,2009, 11:00 AM to 12:00 PM*
- **Kaoru Ono** , Lagrangian Floer theory on symplectic resolutions of singular toric surfaces *November 19,2009, 01:15 PM to 02:15 PM*
- **Ivan Smith** , Fukaya categories of pencils of quadrics *November 19,2009, 02:30 PM to 03:30 PM*
- **Chiu-Chu Liu** , Coherent-constructible correspondence and homological mirror symmetry for toric varieties and toric orbifolds *November 20,2009, 09:30 AM to 10:30 AM*
- **Rahul Pandharipande** , Pairs, BPS states, and knot invariants. *November 20,2009, 11:00 AM to 12:00 PM*
- **Constantin Teleman** , Gauged mirror symmetry and Landau-Ginzburg potentials in the Brauer group *November 20,2009, 01:15 PM to 02:15 PM*
- **Jun Li** , Genus one GW-invariants of quintics revisited *November 20,2009, 02:30 PM to 03:30 PM*
- **Mark Gross** , Log Gromov-Witten invariants *November 20,2009, 04:00 PM to 05:00 PM*

- You can find videos of other workshops and events on our VMath - Streaming Video page.

Participant List

MSRI Workshop:

Algebraic Structures in the Theory of Holomorphic Curves

November 16-20, 2009

at Mathematical Sciences Research Institute, Berkeley California

Name	Institution
Abouzaid, Mohammed	MIT
Akaho, Manabu	Tokyo Metropolitan University
Alston, Garrett	University of Wisconsin
Amorim, Lino Campos	University of Wisconsin
Auroux, Denis	University of California
Bao, Erkao	University of Wisconsin
Bourgeois, Frédéric	Université Libre de Bruxelles
Branson, Mark Alan	Columbia University
Buhovski, Lev	MSRI
Castano-Bernard, Ricardo	Kansas State University
Chan, Ken	Stanford University
Chapin, Jeff Scott	Michigan State University
Chen, Xiaojun	University of Michigan
Cho, Cheol-Hyun	Seoul National University
Choi, Keon	University of California
Cieliebak, Kai J.	Ludwig-Maximilians-Universität München
Coates, Tom	Harvard University
Colin, Vincent	Université de Nantes
Cornea, Octav	University of Montreal
Costello, Kevin	University of Chicago
Cotton-Clay, Andrew	Harvard University
Cueto, Maria Angelica	University of California
Devadoss, Satyan Linus	Williams College
Diogo, Luis Miguel	Stanford University
Dubrovin, Boris	SISSA - International School for Advanced Studies
Ekholm, Tobias	Uppsala University
Etgu, Tolga	Koc University
Fabert, Oliver	Ludwig-Maximilians-Universität München
Fang, Bohan	Northwestern University
Farajzadeh Tehrani, Mohammad	Princeton University
Farris, David	UCB - University of California, Berkeley
Felshtyn, Alexander	University of Szczecin
Finashin, Sergey	Middle East Technical University (ODTU)
Fromm, Viktor	Department of Mathematical Sciences
Fukaya, Kenji	Kyoto University
Gadbled, Agnès	Université de Neuchatel - Institut de Mathématiques
Galatius, Soren	Stanford University
Ganatra, Sheel	Massachusetts Institute of Technology
Georgieva, Penka Vasileva	Stanford University
Getzler, Ezra	Northwestern University
Ghiggini, Paolo	Université de Nantes
Givental, Alexander Boris	University of California
Goberstein, Simon M.	California State University
Goldin, Rebecca Freja	George Mason University
Golovko, Roman	University of Southern California
Gonzalez, Eduardo	University of Massachusetts
Gross, Mark W.	University of California, San Diego
Hofer, Helmut H.	Institute for Advanced Study
Hohloch, Sonja	Tel Aviv University
Hom, Jennifer Cheung	University of Pennsylvania
Huang, Yang	University of Southern California
HUANG, Yi	Georgia Institute of Technology
iacovino, vito	Max-Planck-Institut für Mathematik

Name	Institution
Imagi, Yosuke	Kyoto University
irie, kei	Kyoto University
Itenberg, Ilia	Institut de Recherche Mathématique Avancée de Strasbourg
Jiang, Yunfeng	University of Utah
Johns, Joseph Amos	Barnard College
Joricke, Burglind	MSRI
Joyce, Dominic David	University of Oxford
Juhl, Andreas	Humboldt-Universität
Koelsch, Hans	Springer Science + Business Media LLC
Krawitz, Marc	University of Michigan
Krestiachine, Alexandre	Humboldt-Universität
Kruglikov, Boris S.	University of Tromso
Kutluhan, Cagatay	University of Michigan
Latschev, Janko	Eidgenössische TH Zürich-Zentrum
Le, Van Hong	Czech Academy of Sciences (AVCR)
Lee, Yijen	Purdue University
Lekili, Yanki	Massachusetts Institute of Technology
Li, Jun	Department of Mathematics
Licata, Joan Elizabeth	Stanford University
Lin, Haijian Kevin	University of California
Lipyanskiy, Max	Columbia University
Lisi, Samuel Thomas	Stanford University
Liu, Chiu-Chu	Columbia University
Liu, Xiaobo	University of Notre Dame
LU, Guangcun	Beijing Normal University
Matessi, Diego	Università del Piemonte Orientale ``Amedeo Avogadro''
Ma'u, Sikimeti Luisa	Massachusetts Institute of Technology
Maydanskiy, Maksim	Stanford University
mbiye kalumbu, bienvenu	university of kinshasa
McDuff, Dusa Margaret	Barnard College
McLean, Mark	University of Cambridge
Melvin, Paul M.	Bryn Mawr College
Mikhalkin, Grigory	Université de Genève
Mulase, Motohico	University of California
Müller, Stefan	Korea Institute for Advanced Study (KIAS)
Murphy, Max	Stanford University
Ng, Lenhard L.	Duke University
Nisse, Mounir	Université de Paris VI (Pierre et Marie Curie)
OANCEA, Alexandru	Université de Strasbourg I (Louis Pasteur)
Oh, Yong-Geun	University of Wisconsin
Ohta, Hiroshi	Graduate School of Mathematics, Nagoya University
Ono, Kaoru	Hokkaido University
Ostrover, Yaron	Massachusetts Institute of Technology
Ozbagci, Burak	Koc University
Pandharipande, Rahul	Princeton University
Parker, Brett Damien	University of California
Parker, Thomas H.	Michigan State University
Pascaleff, James Thomas	Massachusetts Institute of Technology
Pedroza, Andrés	Universidad de Colima
Pires, Ana Rita	Massachusetts Institute of Technology
Rasdeaconu, Rares	Hebrew University
Ratiu, Tudor S.	École Polytechnique Fédérale de Lausanne (EPFL)
Rezazadegan, Reza	Rutgers University
Rossi, Paolo	Institut Mathematiques de Jussieu
Ruan, Yongbin	University of Michigan
Sabloff, Joshua M.	Haverford College
Saglam, Nur Kadriye	Middle East Technical University (ODTU)
Schoenfeld, Eric Martin	Michigan State University
Shaw, Kristin Marie	University of Toronto
Smith, Aaron	University of Pennsylvania

Name	Institution
Smith, Ivan	Centre for Mathematical Sciences
Stefanini, Luca	Pennsylvania State University
Subotic, Aleksandar	Harvard University
Takahashi, Atsushi	Osaka University
Teleman, Constantin	University of California
Tseng, Hsian-Hua	Ohio State University
Uyanik, Caglar	Middle East Technical University (ODTU)
Venkatram, Kartik	Boston University
Vertesi, Vera	Alfred Renyi Institute of Mathematics
von Bergmann, Jens	University of Calgary
Wehrheim, Katrin	Massachusetts Institute of Technology
wei, wenzhe	Room 644 Building 45A
Wendl, Chris M	Humboldt-Universität
Woodward, Christopher	Rutgers University
Wu, Weiwei	University of Minnesota Twin Cities
Yau, Mei-Lin	National Central University
Yu, Hao	Minnesota
Zabun, Arzu Remziye	Middle East Technical University (ODTU)
Zhang, Weiyi	Department of mathematics
Zhu, Ke	The Chinese University of Hong Kong, Dept. of Math

Algebraic Structures in the Theory of Holomorphic Curves
Held: November 16-20, 2009
The Mathematical Sciences Research Institute

Officially Registered Participant Information
83 participants

Gender (n = 83 participants)		
Male	85.00%	68
Female	13.75%	11
Declined to state	1.25%	1

Ethnicity (n =83 participants)		
White	58.33%	42
Asian	30.56%	22
Hispanic	1.39%	1
Pacific Islander	0.00%	0
Black	0.00%	0
Native American	0.00%	0
Declined to state	9.72%	7

MSRI Mathematical Sciences Research Institute

Research Workshop:
Symplectic and Contact Topology and Dynamics: Puzzles and Horizons

March 22 to March 26, 2010

MSRI, Berkeley, CA, USA

Organizers:

Paul Biran (Tel Aviv University)

John Etnyre (Georgia Institute of Technology)

Helmut Hofer (Courant Institute)

Dusa McDuff* (Barnard College)

Leonid Polterovich (Tel Aviv University)

Parent Program:

Symplectic and Contact Geometry and Topology

Final Report

Symplectic and Contact Topology and Dynamics: Puzzles and Horizons

March 2010

Organizers:
Paul Biran (Tel Aviv University and ETH-Zürich), John Etnyre (Georgia Institute of Technology), Helmut Hofer (Courant Institute), Dusa McDuff (Barnard College), Leonid Polterovich (Tel Aviv University and University of Chicago)

Summary:

This was the third workshop associated with the "Symplectic and contact geometry and topology" program being held during the 2009-2010 academic year (one more workshop will take place in May, which is sponsored by the Hayashibara foundation and will have an interdisciplinary focus; there is also another related workshop in May, but that is not officially affiliated with the program).

Purpose: The workshop focused on recent progress on central problems in symplectic and contact topology and Hamiltonian dynamics, such as: rigidity of Lagrangian submanifolds; algebra/topology/geometry of symplectomorphism and contactomorphism groups; exotic symplectic and contact structures; and existence of periodic orbits of Hamiltonian systems and Reeb flows. It explained applications of the "large machines" such as Floer Theory, Symplectic Field Theory and Fukaya categories, as well as showing where these machines do not yet provide satisfactory answers. Special attention was paid to articulating new problems and directions, as well as to explaining interactions between symplectic and contact topology and other fields.

Distribution of funding: There were many more requests for funding than could be accomodated. We were able to stretch the given resources quite far, since some of the speakers and participants were already at MSRI as participants in the SCGT program. We gave a high priority to requests from advanced graduate students and beginning researchers, who could benefit most from the exposure to latest results in the field. Limited funding was provided for more senior researchers whose presence would add variety and depth to the workshop. We were able to support a large number of mathematicians at all levels from underrepresented groups.

Some highlights and impact: The workshop started with Taubes' talk on his work with Hutchings, solving the chord conjecture in dimension three (both Taubes and Hutchings were program members while this work was being done). Another notable breakthrough was completed during the workshop itself, since that allowed all collaborators to meet: the proof that $\widehat{ECT} = \widehat{HF}$, announced by Honda on the penultimate day. Many participants emphasized having highly productive discussions during the workshop, which advanced their own research.

Detailed review:

We will now discuss the mathematical content of the talks in more detail, breaking it up into several groups. This is fairly subjective, since the different topics and approaches are closely interrelated.

Contact topology and dynamics: Associated to an oriented contact structure is a natural vector field called the Reeb vector field. This vector field is closely related to Hamiltonian vector fields and its study has been a driving force in contact geometry/topology for some time. In particular two central conjectures in the field are the Weinstein conjecture and the Chord conjecture. The first conjecture postulates the existence of a periodic orbit in the flow of any Reeb vector field, while the second conjecture, which can be thought of as a relative version of the first, postulates, for any Legendrian submanifold of the contact manifold, the existence of segment of a Reeb flow trajectory that begins and ends on the Legendrian submanifold. A couple of years ago Taubes established the Weinstein conjecture in dimension 3. In his talk at this workshop he announced, in joint work with Hutchings, that the Chord conjecture is true in dimension 3. A talk on higher-dimensional Weinstein conjecture, by Oh, caused a lively discussion on analytic aspects of this problem.

Our understanding of contact structures in higher dimensions is at the moment quite limited. In Niederkruger's talk he discussed various obstructions to a contact structure being fillable in higher dimensions and also explored possible notions of "size" or "capacity" in higher dimensions. Sandon's talk also dealt with notions of contact capacities. In her talk she discussed work extending and simplifying some work of Eliashberg, Kim and Polterovich by using generating function techniques.

Wendl discussed notions in dimension 3 that obstruct fillability of contact structures. His notion of k-planar torsion encompasses all previously known obstructions to fillability (like overtwistedness and Giroux torsion) and provides an infinite sequence of more and more subtle obstructions.

Hamiltonian dynamics: Albers and Frauenfelder presented new developments in Rabinowitz Floer Homology, a rapidly developing theory designed for studying dynamics on energy levels of autonomous Hamiltonians.

Hind described new results on the old question "what can be done by a symplectic map?". In particular, he showed the the displacement energy of a polydisc depends in a delicate way on the "size" of the ambient symplectic manifold.

Usher presented a new approach to construction of Calabi quasi-morphisms on groups of Hamiltonian diffeomorphisms as well as a surprising link between Calabi quasi-morphisms and Hofer-Zehnder capacity.

Viterbo outlined foundations of his symplectic homogenization theory which yields a far reaching generalization of Aubry-Mather theory and Gromov-Federer stable norm for non-convex Hamiltonians on cotangent bundles.

Topology of Lagrangian submanifolds: Recent developments in this rapidly developing subject were presented in several talks. Cornea discussed surprising numerical invariants of Lagrangian submanifolds originated in the Lagrangian quantum ring with applications to Lagrangian cobordisms. Damian presented a beautiful version of Lagrangian Floer Homology which incorporates the fundamental group of Lagrangian submanifolds. Lalonde reported on the solution of long-standing homological Lagrangian monodromy problem in the case of weakly exact Lagrangian submanifolds. Schlenk exhibited new constructions of exotic monotone Lagrangian tori in the product of spheres and projective spaces. Abreu announced some new computation concerning classical Lagrangian intersection problems. It is interesting that these computations have been approached from several related, but algebraically different, points of view. Seidel outlined a breath-taking route from the classical singularities theory to a novel count of Lagrangian intersection points.

Relations with low-dimensional topology: Contact topology has been surprisingly useful in illuminating the nature of new invariants of 3-manifolds, most notably the Heegaard-Floer invariant of Ozsváth and Szabó. In Matić's talk she outlined the construction of invariants of contact structures on a three manifold with boundary that live in sutured Heegaard-Floer homology groups. These invariants are not only useful invariants of contact structures but also help one define various gluing maps in Heegaard Floer theory itself. Honda's talk sketched the proof, done in collaboration with Colin and Ghiggini, that $\widehat{HF}(M)$ is isomorphic to $\widehat{ECH}(M)$. This long sought result, coupled with Hutchings and Taubes's identification of $\widehat{ECH}(M)$ and Seiberg-Witten Floer Homology, proves that Heegaard-Floer homology is really the same as Seiberg-Witten Floer homology. A key insight in this proof involves the contact invariants discussed by Matić in her talk.

Relations with other areas: In Abouzaid's talk he gave a beautiful construction of a paralellizable bounding manifold of an exotic smooth sphere that embeds as a Lagrangian submanifold in the cotangent bundle of the standard sphere. This results shows that the symplectic geometry of the cotangent bundle to manifolds can detect subtle differences in the smooth topology of the manifold. In addition, this construction involves an understanding of delicate features of the moduli space of holomorphic curves.

Abreu returned to a classical topic of symplectic and contact manifolds which admit Hamiltonian group actions of maximal dimension. Surprisingly, some of these lead to exotic contact structures on products of spheres. Tori actions on contact manifolds are less understood than their symplectic counterpart. Some foundational issues related to convexity of the image of the contact moment maps were addressed in the talk by Karshon. Tolman presented new topological restrictions on symplectic manifolds admitting Hamiltonian circle actions with "small" fixed point sets.

Finally, Tamarkin described an intriguing approach to the classical symplectic intersection problem based on micro-local analysis of sheaves in the spirit of Kashiwara-Shapira.

Symplectic and Contact Topology and Dynamics: Puzzles and Horizons
March 22 - 26, 2010 at MSRI, Berkeley, CA

Invited Speakers

firstname	lastname	institutionname
Mohammed	Abouzaid	Massachusetts Institute of Technology
Miguel	Abreu	Technical University of Lisbon
Peter	Albers	Purdue University
Octav	Cornea	University of Montreal
Mihai	Damian	IRMA
Urs	Frauenfelder	Seoul National University
Richard	Hind	University of Notre Dame
Ko	Honda	University of Southern California
Yael	Karshon	University of Toronto
François	Lalonde	CRM - Centre de Recherches Mathématiques
Gordana	Matic	University of Georgia
Klaus	Niederkruger	Universite Paul Sabatier--Toulouse III
Yong-Geun	Oh	University of Wisconsin
Sheila	Sandon	Université de Nantes
Felix	Schlenk	Université de Neuchâtel
Paul	Seidel	Massachusetts Institute of Technology
Dmitry	Tamarkin	Northwestern University
Clifford	Taubes	MSRI - Mathematical Sciences Research Institute
Susan	Tolman	University of Illinois at Urbana-Champaign
Michael	Usher	University of Georgia
Claude	Viterbo	École Polytechnique
Chris	Wendl	Humboldt Universität, Berlin

Research Workshop:
Symplectic and Contact Topology and Dynamics: Puzzles and Horizons

March 22 to March 26, 2010, MSRI, Berkeley, CA, USA

Schedule

Monday March 22, 2010		
09:30AM - 10:20AM	Clifford Taubes	Arnold's chord conjecture in dimension 3
10:20AM - 10:50AM	Coffee, tea in the atrium	
10:50AM - 11:40AM	Claude Viterbo	Symplectic Homogenization
11:40AM - 01:20PM	Lunch	
01:20PM - 02:10PM	Octav Cornea	Enumerative invariants and Lagrangian cobordism
02:20PM - 03:10PM	Felix Schlenk	Monotone Lagrangian tori in CP^n and products of spheres
03:10PM - 04:00PM	Coffee, tea in the atrium	
04:00PM - 04:50PM	Mohammed Abouzaid	Framed bordism and Lagrangian embeddings of exotic spheres
Tuesday March 23, 2010		
09:30AM - 10:20AM	Gordana Matic	Contact structures and sutured floer homology
10:20AM - 10:50AM	Coffee, tea in the atrium	
10:50AM - 11:40AM	Sheila Sandon	Application of generating functions to contact rigidity phenomena in R^2n x S1
11:40AM - 01:20PM	Lunch	
01:20PM - 02:10PM	Susan Tolman	Symplectic circle actions with minimal fixed points
02:20PM - 03:10PM	Dmitry Tamarkin	Microlocal condition for non-displaceability
03:10PM - 04:00PM	Coffee, tea in the atrium	
04:00PM - 04:50PM	François Lalonde	Homological Lagrangian Monodromy
Wednesday March 24, 2010		
09:00AM - 10:00AM	Yong-Geun Oh	Weinstein's conjecture on symplectically fillable contact manifolds
10:00AM - 10:30AM	Coffee, tea in the atrium	
10:30AM - 11:30AM	Mihai Damian	Floer homology on the universal cover and lagangion embeddings
11:45AM - 12:45PM	Richard Hind	Embeddings of ellipsoids

Research Workshop:
Symplectic and Contact Topology and Dynamics: Puzzles and Horizons
March 22 to March 26, 2010, MSRI, Berkeley, CA, USA

Thursday March 25, 2010		
09:30AM - 10:20AM	Ko Honda	HF-hat = EC-hat via open book decompositions
10:20AM - 10:50AM	Coffee, tea in the atrium	
10:50AM - 11:40AM	Klaus Niederkruger	Some observations about the size of tubular neighborhoods in contact geometry
11:40AM - 01:20PM	Lunch	
01:20PM - 02:10PM	Michael Usher	Filtered Floer theory and Hamiltonian dynamics
02:20PM - 03:10PM	Urs Frauenfelder	On Rabinowitz Floer homology
03:10PM - 04:00PM	Coffee, tea in the atrium	
04:00PM - 04:50PM	Yael Karshon	Convexity package for momentum maps on contact manifolds
Friday March 26, 2010		
09:30AM - 10:20AM	Peter Albers	Spectral invariants in Rabinowitz Floer homology and applications
10:20AM - 10:50AM	Coffee, tea in the atrium	
10:50AM - 11:40AM	Miguel Abreu	Contact and Lagrangian Floer homologies of toric manifolds
11:40AM - 01:20PM	Lunch	
01:20PM - 02:20PM	Chris Wendl	Open books and fiber sums, SFT and ECH: a plethora of obstructions to symplectic filling
02:20PM - 03:10PM	Paul Seidel	Enhanced intersection numbers
03:10PM - 04:00PM	Coffee, tea in the atrium	

Research Workshop:
Symplectic and Contact Topology and Dynamics: Puzzles and Horizons
March 22 to March 26, 2010, MSRI, Berkeley, CA, USA

Currently Available Videos

- **Clifford Taubes** , Arnold's chord conjecture in dimension 3 *March 22,2010, 09:30 AM to 10:20 AM*
- **Claude Viterbo** , Symplectic Homogenization *March 22,2010, 10:50 AM to 11:40 AM*
- **Octav Cornea** , Enumerative invariants and Lagrangian cobordism *March 22,2010, 01:20 PM to 02:10 PM*
- **Felix Schlenk** , Monotone Lagrangian tori in CP^n and products of spheres *March 22,2010, 02:20 PM to 03:10 PM*
- **Mohammed Abouzaid** , Framed bordism and Lagrangian embeddings of exotic spheres *March 22,2010, 04:00 PM to 04:50 PM*
- **Gordana Matic** , Contact structures and sutured floer homology *March 23,2010, 09:30 AM to 10:20 AM*
- **Sheila Sandon** , Application of generating functions to contact rigidity phenomena in R^2n x S1 *March 23,2010, 10:50 AM to 11:40 AM*
- **Susan Tolman** , Symplectic circle actions with minimal fixed points *March 23,2010, 01:20 PM to 02:10 PM*
- **Dmitry Tamarkin** , Microlocal condition for non-displaceability *March 23,2010, 02:20 PM to 03:10 PM*
- **François Lalonde** , Homological Lagrangian Monodromy *March 23,2010, 04:00 PM to 04:50 PM*
- **Yong-Geun Oh** , Weinstein's conjecture on symplectically fillable contact manifolds *March 24,2010, 09:00 AM to 10:00 AM*
- **Mihai Damian** , Floer homology on the universal cover and lagangion embeddings *March 24,2010, 10:30 AM to 11:30 AM*
- **Richard Hind** , Embeddings of ellipsoids *March 24,2010, 11:45 AM to 12:45 PM*
- **Ko Honda** , HF-hat = EC-hat via open book decompositions *March 25,2010, 09:30 AM to 10:20 AM*
- **Klaus Niederkruger** , Some observations about the size of tubular neighborhoods in contact geometry *March 25,2010, 10:50 AM to 11:40 AM*
- **Michael Usher** , Filtered Floer theory and Hamiltonian dynamics *March 25,2010, 01:20 PM to 02:10 PM*
- **Urs Frauenfelder** , On Rabinowitz Floer homology *March 25,2010, 02:20 PM to 03:10 PM*
- **Yael Karshon** , Convexity package for momentum maps on contact manifolds *March 25,2010, 04:00 PM to 04:50 PM*
- **Peter Albers** , Spectral invariants in Rabinowitz Floer homology and applications *March 26,2010, 09:30 AM to 10:20 AM*
- **Miguel Abreu** , Contact and Lagrangian Floer homologies of toric manifolds *March 26,2010, 10:50 AM to 11:40 AM*
- **Chris Wendl** , Open books and fiber sums, SFT and ECH: a plethora of obstructions to symplectic filling *March 26,2010, 01:20 PM to 02:20 PM*
- **Paul Seidel** , Enhanced intersection numbers *March 26,2010, 02:20 PM to 03:10 PM*

Symplectic and Contact Topology and Dynamics: Puzzles and Horizons

March 22 - 26, 2010 at MSRI, Berkeley, CA

Officially Registered Participants

firstname	lastname	institutionname
Mohammed	Abouzaid	Massachusetts Institute of Technology
Dilip	Abreu	Princeton University
Miguel	Abreu	Technical University of Lisbon
Jiro	Adachi	Hokkaido University
Peter	Albers	Purdue University
Lino	Amorim	University of Wisconsin
Sílvia	Anjos	Technical University of Lisbon
Denis	Auroux	University of California
Marta	Batoreo	University of California
Stefan	Behrens	Max-Planck-Institut für Mathematik
Paul	Biran	Tel Aviv University
Mark	Branson	Columbia University
Olguta	Buse	Indiana University--Purdue University
Andre	Carneiro	Columbia University
Sinem	Celik Onaran	Mathematisches Forschungsinstitut Oberwolfach
Michael	Chance	Vanderbilt University
Jeff	Chapin	Michigan State University
Cheol-Hyun	Cho	Seoul National University
Hyunjoo	Cho	University of Rochester
Vincent	Colin	Université de Nantes
Octav	Cornea	University of Montreal
Andrew	Cotton-Clay	Harvard University
Mihai	Damian	IRMA
Yakov	Eliashberg	Stanford University
Opshtein	Emmanuel	Université de Strasbourg I (Louis Pasteur)
Michael	Entov	Technion---Israel Institute of Technology
Jacqueline	Espina	University of California
Tolga	Etgu	Koc University
Joel	Fish	Stanford University
Urs	Frauenfelder	Seoul National University
Viktor	Fromm	University of Durham
Urs	Fuchs	Purdue University
Agnès	Gadbled	Université de Neuchatel - Institut de Mathématiques
Whitney	George	University of Georgia
Penka	Georgieva	Stanford University
Viktor	Ginzburg	University of California
Rebecca	Goldin	George Mason University
Roman	Golovko	University of Southern California
Brendan	Guilfoyle	Institute of Technology Tralee
Basak	Gurel	Vanderbilt University
Megumi	Harada	McMaster University
Doris	Hein	University of California, Mathematics Department
Richard	Hind	University of Notre Dame
Chung-I	Ho	School of Math
Sonja	Hohloch	Tel Aviv University
Tara	Holm	Cornell University
Ko	Honda	University of Southern California
Umberto	Hryniewicz	Federal University of Rio de Janeiro

Symplectic and Contact Topology and Dynamics: Puzzles and Horizons
March 22 - 26, 2010 at MSRI, Berkeley, CA

firstname	lastname	institutionname
Yosuke	Imagi	Kyoto University
Kei	Irie	Kyoto University
Burglind	Joricke	MSRI
Andras	Juhasz	University of Cambridge
Yael	Karshon	University of Toronto
Will	Kazez	University of Georgia
Ely	Kerman	University of Illinois at Urbana-Champaign
Jin-Hong	Kim	Korean Advanced Institute of Science and Technology (KAIST)
Rafal	Komendarczyk	Tulane University
Robin	Koytcheff	Department of Mathematics, Stanford University
Alexandre	Krestiachine	HU Berlin, Department of Mathematics
François	Lalonde	CRM - Centre de Recherches Mathématiques
Joan	Licata	Stanford University
Max	Lipyanskiy	Columbia University
Samuel	Lisi	Stanford University
Andrew	Lobb	SUNY
Jason	Lotay	Imperial College London
Shisen	Luo	Cornell University
Leonardo	Macarini	Federal University of Rio de Janeiro
Alessia	Mandini	Technical University of Lisbon
Patrick	Massot	Université de Paris XI (Paris-Sud)
Gordana	Matic	University of Georgia
Dusa	McDuff	Barnard College
Isidora	Milin	University of Illinois at Urbana-Champaign
Klaus	Mohnke	Humboldt-Universität
Al	Momin	Purdue University
Max	Murphy	Stanford University
Thomas	Murphy	National University of Ireland, University College Cork
Joanna	Nelson	University of Wisconsin
Lenhard	Ng	Duke University
Klaus	Niederkruger	Universite Paul Sabatier--Toulouse III
Gregor	Noetzel	Max Planck Institute for Mathematics in the Sciences
Yong-Geun	Oh	University of Wisconsin
Joana	Oliveira dos Santos	Université de Paris IX (Paris-Dauphine)
Kaoru	Ono	Department of Mathematics, Hokkaido University
Yaron	Ostrover	Massachusetts Institute of Technology
Michael	OSullivan	San Diego State University
Milena	Pabiniak	Milena Pabiniak
James	Pascaleff	Massachusetts Institute of Technology
Gabriel	Paternain	University of Cambridge
Ana	Pires	Massachusetts Institute of Technology
Rachel	Roberts	Washington University in St. Louis
Yougbin	Ruan	University of Michigan
Joshua	Sabloff	Haverford College
Sheila	Sandon	Université de Nantes
Yakov	Savelyev	University of Massachusets, Amherst
Felix	Schlenk	Université de Neuchâtel
Paul	Seidel	Massachusetts Institute of Technology
Rosa	Sena-Dias	Technical University of Lisbon

Symplectic and Contact Topology and Dynamics: Puzzles and Horizons

March 22 - 26, 2010 at MSRI, Berkeley, CA

firstname	lastname	institutionname
Akram	Sheikhalishahi	Sharif University of Technology
Richard	Siefring	Michigan State University
Alfonso	Sorrentino	DPMMS, University of Cambridge
Michael	Sullivan	University of Massachusetts
Dmitry	Tamarkin	Northwestern University
Clifford	Taubes	MSRI - Mathematical Sciences Research Institute
Susan	Tolman	University of Illinois at Urbana-Champaign
Bulent	Tosun	Georgia Insitute of Technology
Michael	Usher	University of Georgia
Jeremy	Van Horn-Morris	AIM
Anne	Vaugon	Université de Nantes
David	Vela-Vick	Columbia University
Sushmita	Venugopalan	Rutgers University
Ramon	Vera	University of Durham
Vera	Vertesi	MSRI
Renato	Vianna	University of California
Claude	Viterbo	École Polytechnique
Thomas	Vogel	Max-Planck-Institut für Mathematik
Andy	Wand	University of California
Rui	Wang	University of Wisconsin
Joachim	Weber	Humboldt Universität, Berlin
Katrin	Wehrheim	Massachusetts Institute of Technology
Alan	Weinstein	University of California, Berkeley
Chris	Wendl	Humboldt Universität, Berlin
Weiwei	Wu	University of Minnesota Twin Cities
Weiyi	Zhang	Department of mathematics
Ke	Zhu	The Chinese University of Hong Kong
Fabian	Ziltener	University of Toronto

Symplectic and Contact Topology and Dynamics: Puzzles and Horizons

March 22 - 26, 2010 at MSRI, Berkeley, CA

Officially Registered Participant Information

Participants		125

Gender		125
Male	67.20%	84
Female	25.60%	32
Declined to state	7.20%	9

Ethnicity*		129
White	71.32%	92
Asian	17.05%	22
Hispanic	1.55%	2
Pacific Islander	0.00%	0
Black	0.00%	0
Native American	0.00%	0
Declined to state	10.08%	13

* ethnicity specifications are not exclusive

FINAL REPORT
MSRI Connections for Women Workshop
Symplectic and contact geometry and topology
AUGUST 2009

ORGANIZERS:
E. Ionel (Stanford University) D. McDuff (Barnard College)

The main goal of this workshop was to provide a way for women interested in symplectic and contact geometry to meet and get to know each other, partly by hearing talks by one another and partly in more social settings. Many junior women are starting careers in this field and we wanted to provide an opportunity for everyone to hear about their work.

The first morning of the meeting also coincided with the end of a Graduate Student workshop on this topic, and so we started with two survey lectures that were intended both to sum up the work of the previous two weeks for the graduate students and provide an interesting survey of the area for the newcomers.

We also wanted to reinforce people's knowledge of the basics of the field, and so asked all speakers give elementary talks, explaining their terms.

To accomplish these aims we had:

1. **four hour-long talks** by midcareer/senior women, illustrating the breadth of the field. Eleny Ionel and Lisa Traynor, who gave the first two talks, had been thoroughly briefed on the diverse nature of their audience, and managed to find something fresh to say at a good level for everyone. Gordana Matic talked on 3-dimensional contact manifolds, while Susan Tolman talked about recent progress in classifying Hamiltonian circle actions with minimal fixed point set.

2. **six half hour talks** by junior women on a wide variety of topics, with time scheduled in for discussions.

   Of these talks, four (Ionel, Traynor, Ma'u, Gadbled) were on symplectic topology, three were on group actions/dynamical questions (Tolman, Buse, Hohloch) and three were on contact geometry (Matic, Sandon and Pavelescu). This was a good spread of subject matter.

3. **a collection of posters** by four graduate students and postdocs – Margaret Symington organized this.

4. **a panel discussion** led by Tara Holm with participation by Katrin Wehrheim, Lisa Traynor, Susan Tolman, Gordana Matic, and Margaret Symington. The panelists first talked briefly about their career paths and different choices about family issues. Then they answered questions from the audience.

5. **Friday dinner** at a Nepali restaurant.

The participants: There were several groups of participants.

1. **Senior participants.** Symplectic geometry is often considered a field where there are lots of women, but in fact rather few of the more senior women work in symplectic and contact topology, which is the part of the subject that will be emphasized in the year long program. However, there is quite a large group in the related area of equivariant symplectic geometry. Here I am thinking of Yael Karshon, Susan Tolman, Tara Holm, Rebecca Goldin, and younger women such as Megumi Harada and River Chang. So another aim of the conference was to invite these women, and involve them more in the year's activities. They all came except for Rebecca Goldin, and all who did not have to teach stayed for the Introductory Workshop. All of them (including Goldin) are planning further visits in the spring (except for Karshon who is staying on for part of September).

2. **Younger participants.** We gave partial expenses to as many as we could, giving preference to those whom we thought could stay for the Introductory Workshop and profit from it.

3. **Participants from abroad.** There is a very flourishing school of symplectic geometry in Europe and also fledgling groups in East Asia. Three of the postdocs who gave talks were trained in Europe, namely Sandon, Gadbled and Hohloch. We also invited several other women from abroad. This cross fertilization is very important.

Evaluation of the components of the program

The scientific quality was excellent. The hour lecturers gave four different but very good talks. The half hour lectures were also all very interesting, and gave younger women a chance to present their work.

We tried to create a friendly atmosphere in the lecture hall to encourage discussion and questions. For example, the lecturers all gave brief descriptions of their careers to date, so that the audience would know a little about them. Senior members of the audience asked questions and made comments to encourage the others. This seemed to work well.

Also the attempt to facilitate communication between the equivariant group and the symplectic topologists seemed to work. There was some meeting of interests during the *Connections* itself; Susan Tolman's talk was well received, and Olga Buse's short talk was on a related subject. Later on in the Introductory workshop there were many discussions, for example between Yael Karshon and Katrin Wehrheim about the analytic issues in the theory of J-holomorphic curves. Megumi Harada told me that she learnt a lot during this workshop, and is very excited about coming in the spring.

The dinner was definitely worthwhile. One participant (who had earlier expressed some scepticism about events just for women) told me that she had met someone at the dinner whom she would not otherwise have talked to and that was valuable.

Another participant told me during the Introductory Workshop how useful the Connections had been. She said that at a large conference one tends to talk to people one knows, and this gave her a chance to get to know several people. A third told me how illuminating the panel discussion had been; she realised that problems/concerns she had thought hers alone were shared by many others.

Connections : Symplectic and Contact Geometry and Topology

Invited Speakers

Buse, Olguta	Indiana University--Purdue University
Gadbled, Agnès	Université de Neuchatel - Institut de Mathématiques
Goldin, Rebecca Freja	George Mason University
Hohloch, Sonja	Tel Aviv University
Holm, Tara Suzanne	Cornell University
Karshon, Yael	University of Toronto
Lee, Yi-Jen	Purdue University
Liu, Chiu-Chu	Columbia University
Matic, Gordana	University of Georgia
Ma'u, Sikimeti Luisa	Massachusetts Institute of Technology
Pavelescu, Elena	Rice University
Sandon, Sheila	Technical University of Lisbon
Tolman, Susan	University of Illinois at Urbana-Champaign
Traynor, Lisa	Bryn Mawr College
Wehrheim, Katrin	MIT

Connections for Women:

Symplectic and Contact Geometry and Topology

August 14 - 15, 2009

Friday August 14, 2009		
09:00AM - 09:15AM	Welcome	
09:15AM - 10:15AM	Eleny-Nicoleta Ionel	Introduction
10:15AM - 11:00AM	Coffee, Tea in the atrium	
11:00AM - 12:00PM	Lisa Traynor	Explorations in Symplectic Topology via Generating Families
12:00PM - 01:30PM	Lunch	
01:30PM - 02:00PM	Sikimeti Ma'u	Quilted disks, multiplihedra, and A_∞ functors
02:00PM - 02:10PM	Informal Discussion	
02:10PM - 02:15PM	Break	
02:15PM - 02:45PM	Agnès Gadbled	Monotone Lagrangian embeddings into cotangent bundles
02:45PM - 02:55PM	Informal discussion	
03:00PM - 04:00PM	Coffee, Tea in the Atrium	
04:00PM - 05:00PM	Gordana Matic	Contact invariant in Sutured Floer Homology
Saturday, August 15, 2009		
09:00AM - 10:00AM	Susan Tolman	Symplectic circle actions with minimal fixed sets
10:00AM - 10:30AM	Coffee, Tea in the Atrium	
10:30AM - 11:00AM	Sonja Hohloch	Homoclinic points and Floer homology
11:00AM - 11:10AM	Informal discussion	
11:10AM - 11:15AM	Break	
11:15AM - 11:45AM	Sheila Sandon	Contact Non-Squeezing via Generating Functions
11:45AM - 12:00PM	Informal discussion	
12:00PM - 01:30PM	Lunch	
01:30PM - 02:00PM	Olguta Buse	Topology of symplectomorphism groups
02:00PM - 02:15PM	Informal discussion	
02:10PM - 02:15PM	Break	
02:15PM - 02:45PM	Elena Pavelescu	The self-linking number in annulus open book decompositions
02:45PM - 02:55PM	Informal discussion	
03:00PM - 04:00PM	Coffee, tea in the atrium	
04:00PM - 05:30PM	Panel	

Currently Available Videos

- **Sikimeti Ma'u** , Quilted disks, multiplihedra, and A_∞ functors *August 14,2009, 01:30 PM to 02:00 PM*
- **Agnès Gadbled** , Monotone Lagrangian embeddings into cotangent bundles *August 14,2009, 02:15 PM to 02:45 PM*
- **Ivan Matic** , Contact invariant in Sutured Floer Homology *August 14,2009, 04:00 PM to 05:00 PM*
- **Susan Tolman** , Symplectic circle actions with minimal fixed sets *August 15,2009, 09:00 AM to 10:00 AM*
- **Sonja Hohloch** , Homoclinic points and Floer homology *August 15,2009, 10:30 AM to 11:00 AM*
- **Sheila Sandon** , Contact Non-Squeezing via Generating Functions *August 15,2009, 11:15 AM to 11:45 AM*
- **Olguta Buse** , Topology of symplectomorphism groups *August 15,2009, 01:30 PM to 02:00 PM*
- **Elena Pavelescu** , The self-linking number in annulus open book decompositions *August 15,2009, 02:15 PM to 02:45 PM*

Participant List

MSRI Workshop:

Connections for Women: Symplectic and Contact Geometry and Topology

August 14-15, 2009

at Mathematical Sciences Research Institute, Berkeley California

Name	Institution
Pabiniak, Milena Dorota	Cornell University
Thompson, Meagan	Harvard University
Georgieva, Penka Vasileva	Stanford University
Nelson, Joanna	University of Wisconsin
Buse, Olguta	Indiana University--Purdue University
Kim, Hee Jung	Louisiana State University
Manjarin, Monica	Université de Rennes I
Sandon, Sheila	Technical University of Lisbon
Gadbled, Agnès	Université de Neuchatel - Institut de Mathématiques
Celik Onaran, Sinem	Middle East Technical University (ODTU)
Cho, Hyunjoo	University of Rochester
Mahmood, Fatima	Cornell University
Pavelescu, Elena	Rice University
Traynor, Lisa	Bryn Mawr College
Liu, Chiu-Chu	Columbia University
Ma'u, Sikimeti Luisa	Massachusetts Institute of Technology
Wehrheim, Katrin	MIT
Karshon, Yael	University of Toronto
Tolman, Susan	University of Illinois at Urbana-Champaign
Goldin, Rebecca Freja	George Mason University
Lee, Yi-Jen	Purdue University
Harada, Megumi	McMaster University
Holm, Tara Suzanne	Cornell University
Gurel, Basak Zehra	Vanderbilt University
Rechtman, Ana	UMPA
O'Donnol, Danielle	Rice University
Shaw, Kristin Marie	University of Toronto
Medetogullari, Elif	Middle East Technical University (ODTU)
Hohloch, Sonja	Tel Aviv University
Wade, Aissa	Pennsylvania State University
Ionel, Eleny-Nicoleta	Stanford University
Barreto Felipe, Yadira Lizeth	National Autonomous University of Mexico (UNAM)
Sena-Dias, Rosa	Technical University of Lisbon
Anjos, Sílvia Ravasco	Technical University of Lisbon
Cahn, Patricia	Dartmouth College
Symington, Margaret Fife	Mercer University
Hom, Jennifer Cheung	University of Pennsylvania
Yilmaz, Elif	Middle East Technical University (ODTU)
Matic, Gordana	University of Georgia
Chiang, River	National Cheng Kung University
Hein, Doris	University of California
Vaugon, Anne	Université de Nantes
diansuy, maria ailynn aviles	University of the East
Beyaz, Ahmet	Department of Mathematics
Shiu, Anne J.	University of California
Espina, Jacqueline	University of California
Hong, hansol	Seoul National University
Vertesi, Vera	Alfred Renyi Institute of Mathematics
chu, karene	University of Toronto
hilario, richard a	
Montgomery, Whitney	University of Georgia
Mansfield, Laura	Bryn Mawr College
Lu, Ni	University of Hawaii at Manoa

Milin, Isidora	University of Illinois at Urbana-Champaign
Cho, Cheol-Hyun	Seoul National University

Connections for Women: Symplectic and Contact Geometry and Topology
Held: August 14-15, 2009
The Mathematical Sciences Research Institute

Officially Registered Participant Information
55 participants

Gender (n = 55participants)		
Male	9.09%	5
Female	90.91%	50
Declined to state	0.00%	0

Ethnicity (n =55 participants)		
White	60.00%	33
Asian	29.09%	16
Hispanic	3.64%	2
Pacific Islander	1.82%	1
Black	1.82%	1
Native American	0.00%	0
Declined to state	3.64%	2

Final Report
Introductory Workshop
Symplectic and contact geometry and topology
August 2009

Organizers:
J. Etnyre (Georgia Institute of Technology)
D. McDuff (Columbia University)
L. Traynor (Bryn Mawr College)

This was the Introductory Workshop for the year long program "Symplectic and contact geometry and topology" being held during the 2009-2010 academic year. The audience was made up of a broad array of people including graduate students, post-docs, and established researchers in the symplectic and contact fields as well as other closely related subjects. The workshop served two main purposes: (1) to introduce people to a broad swath of the field, and (2) to frame the most important problems and subareas in order to give some shape to the year long program.

While not able to cover this immense field completely, we focused on four broad areas that will be the basis for most of the activities during the coming year. We also took into account the request of the organizers of the Fall Tropical Geometry program to emphasize the kind of holomorphic curves that could be counted. Specifically we focused on (a) *Symplectic field theory*, (b) *Floer homology*, (c) *Topological aspects*, and (d) *Applications*. For each topic we had a blend of mini-courses introducing the main ideas of the area and a few other talks aimed at exposing the lay of the land and future directions for the field. In addition we had two very introductory lectures introducing the history and basic ideas in symplectic and contact geometry and topology. Generous breaks between the lectures were also built into the workshop to allow the participants time to interact with the speakers and amongst themselves.

To achieve the broadest possible perspectives on these subjects we asked two experts in each area, (a)–(d) above, to organize the activities in that area. Specifically we had Y. Eliashberg and H. Hofer organize the Symplectic field theory talks; M. Abouzaid and P. Albers organize the Floer talks; D. Auroux and K. Honda organize the topological aspects talks; and L. Traynor and M. Entov organize the applications talks. This resulted in the selection of a wide variety of speakers, ranging from well established leaders of the field to several postdocs and junior faculty.

Content of the talks: We will not describe the details of each talk but list the speakers for each subject area and discuss the main points that were conveyed.

Introductory talks: Speaker — Dusa McDuff. In these, the first two talks of the workshop, the basic definitions and examples of symplectic structures, contact structure, Hamiltonian flows, etc. were introduced. The first lecture went on to discuss of some of the questions (such as the Arnold and Weinstein conjectures) that strongly influenced the development of the field as well as those that drive much current research. The second lecture described the basic elements of Gromov's theory of pseudo-holomorphic curves, since this is the crucial idea behind all current work in the field.

Symplectic field theory: Speakers — Helmut Hofer, Yasha Eliashberg, Paolo Rossi, Katrin Wehrheim. Symplectic field theory is an elaborate framework for capturing information given by holomorphic curves in symplectic manifolds. Originally conceived by Eliashberg, Givental and Hofer it is actively being developed to this day. The talks focused on the algebraic framework of the theory and the analytic tools needed to define the theory rigorously. In particular, there were several talks on scale calculus and polyfolds.

Floer homology: Speakers — Mohammed Abouzaid, Peter Albers, Sikimeti M'au, Mark McLean. There are many variants of Floer theory. These lectures focused on Hamiltonian Floer theory, Lagrangian Floer theory and symplectic homology. They discussed successes of the theory and several applications as well as limitations and current challenges within the theory.

Topological aspects: Speakers — Denis Auroux, John Etnyre, Ko Honda, Maksim Maydanskiy. The introduction of Lefschetz pencils (fibrations) in symplectic geometry and open book decompositions in contact geometry have transformed many questions in symplectic and contact geometry into questions with a more topological flavor (especially in dimensions 3 and 4). These connections were described and many applications were discussed during these lectures. Convex surfaces, another fundamental topological tool in 3 dimensional contact geometry, were also surveyed.

Applications: Speakers — Octav Cornea, Michael Entov, Victor Ginzburg, Lenny Ng. This series of lectures consisted in a wide sampling of the many diverse applications of symplectic and contact geometry and topology to other areas as well as applications of some of the sophisticated machinery from other lectures being applied to symplectic geometry itself. For example, connections with invariants of smooth knots in 3-manifolds and applications to quantum mechanics and Hamiltonian dynamics were discussed, as well as new perspectives on the geometry of Lagrangian submanifolds.

Problem session: Organizer – Lisa Traynor. Participants of the workshop were invited to share problems that would be good to think about during the coming year. Dusa McDuff began by introducing a number of intriguing questions including some unknown questions about the connectedness of some groups of symplectomorphisms. Helmut Hofer urged people to try to construct bizarre embeddings of ellipsoids since this will help us understand if there are gaps in what SFT can detect. Mohammed Abouzaid discussed a known theorem that states that a Lagrangian torus inside T^4 is theoretically equivalent to some linear Lagrangian and then posed the question of whether this remains true when T^4 is replace by a more general product of Riemann surfaces. Knowledge about this would have applications to mirror symmetry. Yasha Eliashberg introduced a number of interesting problems. He urged us to think of some "overly optimistic" conjectures, for example generalizations of the Arnold conjectures or the statement that *every* odd dimensional manifold (with stable almost complex structure) is contact, and then either prove or find counterexamples to these conjectures. Eliashberg also highlighted an important question about how SFT changes when a handle is attached to a manifold. Lastly, Octav Cornea introduced a version of symplectic embeddings relative to to a pair of Lagrangian submanifolds and posed some questions that compare the maximal "width" of such an embedding to the Hofer distance between the Lagrangians.

Distribution of the funding:

There were many more requests for funding than could be honored. We were able to stretch the funding quite far since some of the speakers and participants were already at MSRI because of the earlier Graduate and Connections for Women Workshops. We gave a high priority to requests of post-docs/young faculty since this workshop provided an excellent opportunity to find new areas of research at this important time in their career. We had numerous requests from graduate students at a variety of levels. Since a high level of mathematical maturity was needed to understand the lectures, we gave preference to the more advanced graduate students who were working in or had independently studied topics related to the workshop. We decided to give additional support to some of the Research Members (specially those attending the program for shorter periods that did not overlap with the workshop) since we thought that their attendance at the introductory workshop would encourage interactions and collaborations throughout the year.

Conclusion: Several people commented to the organizers that some of the talks in areas they knew less well helped clarify a new aspect of the field for them. We also heard comments from some of the graduate students who had attended the earlier Graduate Workshop that they had understood most of the talks in the Introductory workshop and felt they had a good overview of the field. Repeated comments of this sort, and the attendance of many of the talks by MSRI members not associated with the symplectic and contact program, allow us to conclude that the workshop certainly met its first stated goal above. There is also every indication that the second goal was achieved as well, given that the organizers carefully consulted with the organizing committee for the year long program (two of the organizers are also on that committee). However the ultimate test will be the ease with which the symplectic and contact year begins.

Introductory : Symplectic and Contact Geometry and Topology

Invited Speakers

Etnyre, John	Georgia Institute of Technology
McDuff, Dusa Margaret	Barnard College
Traynor, Lisa	Bryn Mawr College
Abouzaid, Mohammed	MIT
Albers, Peter	Purdue University
Rossi, Paolo	École Polytechnique
Entov, Michael	Technion (Israel Institute of Technology)
Auroux, Denis	University of California
Honda, Ko	Univ. of Southern California
Eliashberg, Yakov	Stanford University
Ng, Lenhard L.	Duke University
Maydanskiy, Maksim	Stanford University
Wehrheim, Katrin	MIT
Hofer, Helmut H.	New York University
Cornea, Octav	University of Montreal
McLean, Mark	University of Cambridge
Ginzburg, Victor A.	University of California

MSRI Mathematical Sciences Research Institute

Introductory Workshop:

Symplectic and Contact Geometry and Topology

August 17, 2009 to August 21, 2009

Monday August 17, 2009		
09:00AM - 09:15AM	Welcome to MSRI	
09:15AM - 10:15AM	Dusa McDuff	Historical overview, motivating problems and basic background
10:15AM - 11:00AM	Coffee, tea in the atrium	
11:00AM - 12:00PM	Dusa McDuff	Basic background, ctd
12:00PM - 01:30PM	Lunch	
01:30PM - 03:00PM	Peter Albers	Floer Homology
03:00PM - 03:45PM	Coffee, tea in the atrium	
03:45PM - 05:00PM	Sikimeti M'au -- Lagrangian Floer Homology	
Tuesday August 18, 2009		
09:00AM - 10:15AM	Mohammed Abouzaid	Obstruction in Lagrangian Floer Theory
10:15AM - 11:00AM	Coffee, tea in the atrium	
11:00AM - 12:00PM	Mark McLean	Symplectic Homology
12:00PM - 01:45PM	Lunch	
01:45PM - 03:00PM	Yakov Eliashberg	Algebraic formalism of Symplectic Field Theory (SFT)
03:00PM - 03:45PM	Coffee, tea in the atrium	
03:45PM - 05:00PM	Helmut Hofer	Analytic foundations of SFT
05:00PM - 06:00PM	Reception in the atrium	
Wednesday August 19, 2009		
09:00AM - 10:15AM	John Etnyre	Open book decompositions and the Giroux correspondence
10:15AM - 11:00AM	Coffee, tea in the atrium	
11:00AM - 12:00PM	Denis Auroux	Lefschetz fibrations and 4-manifolds
12:00PM - 01:45PM	Lunch	
01:45PM - 03:00PM	Yakov Eliashberg	Algebraic formalism of SFT ctd
03:00PM - 03:45PM	Coffee, tea in the atrium	
03:45PM - 05:00PM	Helmut Hofer	Analytic foundations of SFT ctd
Thursday August 20, 2009		
09:00AM - 10:15AM	Ko Honda	Convex surfaces and classification of contact structures
10:15AM - 11:00AM	Coffee, tea in the atrium	
11:00AM - 12:00PM	Katrin Wehrheim	"Analytic foundations: polyfold structures for holomorphic disks"
12:00PM - 01:45PM	Lunch	
01:45PM - 03:00PM	Lenhard Ng	Knot homology
03:00PM - 04:00PM	Coffe, tea inthe atrium	
04:00PM - 05:00PM	Octav Cornea	Wide - narrow dichotomy for Lagrangians submanifolds
Friday August 21, 2009		
09:00AM - 10:00AM	Paolo Rossi	Integrable systems of SFT
10:00AM - 10:30AM	Coffee, tea in the atrium	
10:30AM - 11:20AM	Maksim Maydanskiy	High dimensional Lefschetz fibrations and Floer homology
11:30AM - 12:20PM	Lisa Traynor	Problem session (maybe overlap with lunch)
12:00PM - 02:00PM	Lunch	
02:00PM - 03:00PM	Michael Entov	Quasi-states and quasi-morphisms in symplectic topology
03:00PM - 04:00PM	Coffee, tea in the atrium	
04:00PM - 05:00PM	Victor Ginzburg	Periodic orbits in Hamiltonian dynamics

Currently Available Videos

- **Lenhard Ng** , Knot homology *August 20,2008, 01:45 PM to 03:00 PM*
- **Dusa McDuff** , Historical overview, motivating problems and basic background *August 17,2009, 09:15 AM to 10:15 AM*
- **Dusa McDuff** , Basic background, ctd *August 17,2009, 11:00 AM to 12:00 PM*
- **Peter Albers** , Floer Homology *August 17,2009, 01:30 PM to 03:00 PM*
- **Sikimeti Ma'u** , Lagrangian Floer Homology *August 17,2009, 03:45 PM to 05:00 PM*
- **Mohammed Abouzaid** , Obstruction in Lagrangian Floer Theory *August 18,2009, 09:00 AM to 10:15 AM*
- **Mark McLean** , Symplectic Homology *August 18,2009, 11:00 AM to 12:00 PM*
- **Yakov Eliashberg** , Algebraic formalism of Symplectic Field Theory (SFT) *August 18,2009, 01:45 PM to 03:00 PM*
- **Helmut Hofer** , Analytic foundations of SFT *August 18,2009, 03:45 PM to 05:00 PM*
- **John Etnyre** , Open book decompositions and the Giroux correspondence *August 19,2009, 09:00 AM to 10:15 AM*
- **Denis Auroux** , Lefschetz fibrations and 4-manifolds *August 19,2009, 11:00 AM to 12:00 PM*
- **Yakov Eliashberg** , Algebraic formalism of SFT ctd *August 19,2009, 01:45 PM to 03:00 PM*
- **Helmut Hofer** , Analytic foundations of SFT ctd *August 19,2009, 03:45 PM to 05:00 PM*
- **Ko Honda** , Convex surfaces and classification of contact structures *August 20,2009, 09:00 AM to 10:15 AM*
- **Katrin Wehrheim** , Analytic foundations: polyfold structures for holomorphic disks *August 20,2009, 11:00 AM to 12:00 PM*
- **Octav Cornea** , Wide - narrow dichotomy for Lagrangians submanifolds *August 20,2009, 04:00 PM to 05:00 PM*
- **Paolo Rossi** , Integrable systems of SFT *August 21,2009, 09:00 AM to 10:00 AM*
- **Maksim Maydanskiy** , High dimensional Lefschetz fibrations and Floer homology *August 21,2009, 10:30 AM to 11:20 AM*
- **Lisa Traynor** , Problem session *August 21,2009, 11:30 AM to 12:20 PM*
- **Michael Entov** , Quasi-states and quasi-morphisms in symplectic topology *August 21,2009, 02:00 PM to 03:00 PM*
- **Victor Ginzburg** , Periodic orbits in Hamiltonian dynamics *August 21,2009, 04:00 PM to 05:00 PM*

You can find videos of other workshops and events on our VMath - Streaming Video page.

Participant List

MSRI Workshop:

Introductory Workshop: Symplectic and Contact Geometry and Topology

August 17-21, 2009

at Mathematical Sciences Research Institute, Berkeley California

Name	Institution
Abouzaid, Mohammed	MIT
Adachi, Jiro	Hokkaido University
Ahmad, Muhammad Naeem	Kansas State University
Albers, Peter	Purdue University
Anjos, Sílvia Ravasco	Technical University of Lisbon
ARSLAN, AYKUT	Michigan State University
Auroux, Denis	University of California
Azimian, Amin	Islamic Azad University,South Tehran
Bailey, Michael	University of Toronto
Bao, Erkao	University of Wisconsin
Barreto Felipe, Yadira Lizeth	National Autonomous University of Mexico (UNAM)
Baykur, Refik Inanc	Brandeis University
Beyaz, Ahmet	Department of Mathematics
Bounya, Cedric	École Normale Supérieure
Branson, Mark Alan	Columbia University
Buhovski, Lev	Tel Aviv University
Buse, Olguta	Indiana University--Purdue University
Cahn, Patricia	Dartmouth College
Carneiro, Andre	Columbia University
castaneda, candelario	University of New Mexico
Celik Onaran, Sinem	Middle East Technical University (ODTU)
Chapin, Jeff Scott	Michigan State University
Charette, Francois	University of Montreal
Chiang, River	National Cheng Kung University
Cho, Cheol-Hyun	Seoul National University
Cho, Hyunjoo	University of Rochester
Choi, Ka	University of California
Choi, Keon	University of California
chu, karene	University of Toronto
Cornea, Octav	University of Montreal
Cristofaro-Gardiner, Daniel	University of California
Dave, Shantanu	Faculty of Mathematics, University of Vienna
Dechang, Chen	University of Massachusetts
diansuy, maria ailynn aviles	University of the East
Diogo, Luis Miguel	Stanford University
Eliashberg, Yakov	Stanford University
Entov, Michael	Technion (Israel Institute of Technology)
Espina, Jacqueline	University of California
Etgu, Tolga	Koc University
Etnyre, John	Georgia Institute of Technology
Fabert, Oliver	Ludwig-Maximilians-Universität München
Fok, Chi-Kwong	Cornell University
Frankel, Steven	California Institute of Technology
Fromm, Viktor	Department of Mathematical Sciences
Gadbled, Agnès	Université de Neuchatel - Institut de Mathématiques
Ganatra, Sheel	Massachusetts Institute of Technology
Georgieva, Penka Vasileva	Stanford University
GEORGIOU, NIKOS	Institute of Technology Tralee
Gerstenberger, Andreas	Ludwig-Maximilians-Universität München
Ginzburg, Victor A.	University of California
Gospodinov, Georgi Donev	Olin College of Engineering
Grigoriev, Ilya	Stanford University
Gripp, Vinicius	University of California

Harada, Megumi	McMaster University
Harvey, Shelly	Rice University
Hays, Chris	Michigan State University
Hein, Doris	University of California
Hengesbach, Conrad	University of California
Herold, Matthias	TU Kaiserslautern
Herr, Daniel	University of Massachusetts
hilario, richard a	
Ho, Chung-I	University of Minnesota Twin Cities
Ho, Nan-Kuo	National Tsing Hua University
Hofer, Helmut H.	<none>
Hohloch, Sonja	Tel Aviv University
Honda, Ko	Univ. of Southern California
Hong, hansol	Seoul National University
Huang, Yang	University of Southern California
Hutchings, Michael L.	University of California
Hwang, Cheuk-Man	Michigan State University
Islam, Md. Rabiul	St. Xavier's College
Johns, Joseph Amos	Columbia University
Juhl-Jöricke, Burglind Elisabeth Jutta	Institut des Hautes Études Scientifiques (IHES)
Kaloti, Amey	Georgia Institute of Technology
Kang, Jungsoo	Seoul National University
Karakurt, Cagri	Michigan State University
Karshon, Yael	University of Toronto
Kim, Hee Jung	Louisiana State University
Kim, Taechan	Seoul National University
Krouglov, Vladimir	Institute for the Low Temperature Physics
Kusner, Robert Barnard	University of Massachusetts
LaFountain, Doug	University at Buffalo (SUNY)
Lanzat, Sergei	Technion---Israel Institute of Technology
Lee, Ju A	Seoul National University
Lee, Sangwook	Seoul National University
Lev, Baruch	
Li, Jiayong	University of Toronto
Li, Youlin	Shanghai Jiaotong University
Lidman, Tye	University of California
Lisi, Samuel Thomas	Stanford University
Liu, Chiu-Chu	Columbia University
Mahmood, Fatima	Cornell University
Manjarin, Monica	Université de Rennes I
Marathe, Kishore B.	State University College, SUNY
Ma'u, Sikimeti Luisa	Massachusetts Institute of Technology
Maydanskiy, Maksim	Stanford University
McDuff, Dusa Margaret	Barnard College
McLean, Mark	University of Cambridge
Medetogullari, Elif	Middle East Technical University (ODTU)
Melvin, Paul M.	Bryn Mawr College
Mensah, Solomon Dietey	A+ Group (Mathematics Section)
Michael, Brandenbursky	Technion
Murphy, Max	Stanford University
Murphy, Thomas	National University of Ireland, University College Cork
Nairn, Kristen Ann	St. John's University
Nelson, Joanna	University of Wisconsin
Nesci, Michele	Université de Genève
Ng, Lenhard L.	Duke University
Nisse, Mounir	Université de Paris VI (Pierre et Marie Curie)
Obeng-Asante, Joseph	A+ Group (Mathematics Section)
O'Donnol, Danielle	Rice University
Ozbagci, Burak	Koc University
Pabiniak, Milena Dorota	Cornell University
Park, Heesang	Seoul National University

Park, Jongil	Seoul National University
Pascaleff, James Thomas	Massachusetts Institute of Technology
Pasquotto, Federica	Vrije Universiteit
Pati, Justin	University of New Mexico
Pavelescu, Elena	Rice University
Pedroza, Andrés	Universidad de Colima
Plamenevskaya, Olga	SUNY
Prokhorenkov, Igor	Texas Christian University
Rezazadegan, Reza	Rutgers University
Rieser, Antonio Peter	<none>
Rossi, Paolo	École Polytechnique
Rutherford, Dan	Duke University
Salur, Sema	Northwestern University
Sandon, Sheila	Technical University of Lisbon
Savelyev, Yakov	University of Massachusets, Amherst
Scharlemann, Martin G.	University of California
Sena-Dias, Rosa	Technical University of Lisbon
Seyfaddini, Sobhan	University of California
Shaw, Kristin Marie	University of Toronto
Shelukhin, Egor	Tel Aviv University
Sheridan, Nicholas James	Massachusetts Institute of Technology
Siefring, Richard	Michigan State University
Smith, Aaron	University of Pennsylvania
Subotic, Aleksandar	Harvard University
Sung, C.J.	National Tsing Hua University
Sung, Chiung-Jue	National Tsing Hua University
Tolman, Susan	University of Illinois at Urbana-Champaign
Torres, Rafael	Max Planck Institute for Mathematics
Tosun, Bulent	Georgia Insitute of Technology
Traynor, Lisa	Bryn Mawr College
Tweedy, Eamonn	University of California
Van Horn-Morris, Jeremy	University of Quebec
Vaugon, Anne	Université de Nantes
Vertesi, Vera	Alfred Renyi Institute of Mathematics
Vianna, Renato Ferreira de Velloso	Institute of Pure and Applied Mathematics (IMPA)
Walker, Björn	
Wang, Dongning	University of Wisconsin
Watts, Jordan	University of Toronto
Wehrheim, Katrin	Massachusetts Institute of Technology
wei, wenzhe	Beijing (Peking) University
Williams, Michael John	University of California
Wolbach, Aaron	University of Massachusetts
Wu, Weiwei	University of Minnesota Twin Cities
Wu, Zhongtao	Princeton University
Yilmaz, Elif	Middle East Technical University (ODTU)
Zhan, Cheng	Rice University

Introductory Workshop: Symplectic and Contact Geometry and Topology
Held: August 17-21, 2009
The Mathematical Sciences Research Institute

Officially Registered Participant Information
160 participants

Gender (n = 160participants)		
Male	63.75%	102
Female	27.50%	44
Declined to state	8.75%	14

Ethnicity (n =146 participants)		
White	63.01%	92
Asian	30.82%	45
Hispanic	2.74%	4
Pacific Islander	0.68%	1
Black	2.05%	3
Native American	0.68%	1
Declined to state	0.00%	0

Mathematical Sciences Research Institute

Symplectic and Poisson Geometry in interaction with Algebra, Analysis and Topology

May 04, 2010 to May 07, 2010

MSRI, Berkeley, CA, USA

MSRI did not receive the scientific report from the organizers because they independently reported this activity. Please note, this workshop was not funded by the NSF.

Symplectic and Poisson Geometry in interaction with Algebra, Analysis and Topology

May 04, 2010 to May 07, 2010

Organized by: Yakov Eliashberg (Stanford University), Alvaro Pelayo (University of California, Berkeley), Steve Zelditch (Northwestern University), Maciej Zworski (University of California, Berkeley)*

The first week of May 2010 coincided with the first year anniversary of Alan Weinstein's retirement from UC Berkeley. Weinstein has been one of the most influential figures in symplectic geometry, Poisson geometry, and analysis in the past forty years. Weinstein's fundamental work inspired many researcher and led to the development of central concepts in symplectic and Poisson geometry and to the establishment of symplectic geometry as an independent discipline within mathematics. This conference was a forum to celebrate Weinstein's fundamental contributions to geometry and mathematics at large.

Symplectic and Poisson Geometry in interaction with Algebra, Analysis and Topology

May 4 - 7, 2010

Officially registered participants		
firstname	lastname	institutionname
Mélanie	Bertelson	Université Libre de Bruxelles
James	Bland	Georgia Southern University
Robert	Bryant	MSRI
Henrique	Bursztyn	Institute of Pure and Applied Mathematics (IMPA)
Santiago	Canez	University of California, Berkeley
Bianca	Cerchiai	Università di Milano
QINGTAO	CHEN	Univeristy of Southern California
Marius	Crainic	Rijksuniversiteit te Utrecht
Chris	Croke	University of Pennsylvania
Kiril	Datchev	University of California
Luis	Diogo	Stanford University
David	Duncan	Rutgers University
Yakov	Eliashberg	Stanford University
Chi-Kwong	Fok	Cornell University
Kenji	Fukaya	Kyoto University
Ezra	Getzler	Northwestern University
Grégory	Ginot	Université de Paris VI (Pierre et Marie Curie)
Viktor	Ginzburg	University of California
Roman	Golovko	University of Southern California
Alfonso	Gracia-Saz	University of Toronto
Victor	Guillemin	Massachusetts Institute of Technology
Michael	hall	University of California
Conrad	Hengesbach	University of California
Michael	Hitrik	University of California
Sonja	Hohloch	Tel Aviv University
Tara	Holm	
Theo	Johnson-Freyd	University of California
Burglind	Joricke	
Benoit	Jubin	University of California
Holger	Kammeyer	University of California
Shoshichi	Kobayashi	University of California
Yvette	Kosmann-Schwarzbach	Centre de Mathématiques Laurent Schwartz, Ecole Polytecnique
Bertram	Kostant	Massachusetts Institute of Technology
Jiayong	Li	University of Toronto
Yi	Lin	Georgia Southern University
Jiang-Hua	Lu	University of Hong Kong
Shisen	Luo	Cornell University
Alessia	Mandini	Technical University of Lisbon
Dusa	McDuff	Barnard College
Mark	McLean	Massachusetts Institute of Technology
Richard	Montgomery	UCSC
Max	Murphy	Stanford University
Thomas	Murphy	National University of Ireland, University College Cork
Yong-Geun	Oh	University of Wisconsin
Brett	Parker	University of California
Michael	Pejic	University of California
Alvaro	Pelayo	University of California

Symplectic and Poisson Geometry in interaction with Algebra, Analysis and Topology
May 4 - 7, 2010

firstname	lastname	institutionname
Ana	Pires	Massachusetts Institute of Technology
Petya	Pushkar	Université Libre de Bruxelles
Tudor	Ratiu	École Polytechnique Fédérale de Lausanne (EPFL)
Nicolai	Reshetikhin	UCB - University of California, Berkeley
Chris	Rogers	University of California
Yanir	Rubinstein	Stanford University
Jenny	Santoso	University of Stuttgart
Yakov	Savelyev	University of Massachusets, Amherst
Pierre	Schapira	Université de Paris VI (Pierre et Marie Curie)
Graeme	Segal	Oxford University
Paul	Skerritt	California Institute of Technology
Daniel	Sternheimer	Keio University, Department of Mathematics
Mathieu	Stienon	Université de Paris VII (Denis Diderot)
Makiko	Tanaka	Science University of Tokyo
Clifford	Taubes	MSRI - Mathematical Sciences Research Institute
Peter	Teichner	UCB - University of California, Berkeley
Vera	Vertesi	MSRI
Renato	Vianna	University of California
Joseph	Viola	University of California
San	Vu Ngoc	Université de Rennes I
Christophe	WACHEUX	Université de Rennes I
Alan	Weinstein	UC, Berkeley
Joseph	Wolf	University of California
Ping	Xu	Centre Universitaire de Luxembourg
Marco	Zambon	Autonomous University of Madrid
Steven	Zelditch	Steve Zelditch
Maciej	Zworski	UCB - University of California, Berkeley

Mathematical Sciences Research Institute

Symplectic Geometry, Noncommutative Geometry and Physics

May 10, 2010 to May 14, 2010

MSRI, Berkeley, CA, USA

Organizers:

Robbert Dijkgraaf (Amsterdam)
Tohru Eguchi (Kyoto)
Yakov Eliashberg* (Stanford)
Kenji Fukaya (Kyoto)
Yoshiaki Maeda* (Yokohama)
Dusa McDuff (Stony Brook)
Paul Seidel (Cambridge, MA)
Alan Weinstein* (Berkeley)

Sponsor:

Hayashibara Foundation

Report on the Hayashibara Forum on Symplectic Geometry, Noncommutative Geometry and Physics

October 29, 2010

Organizers:

- Robert Dijkgraaf (Amsterdam)
- Tohru Eguchi (Kyoto)
- Yakov Eliashberg (Stanford)
- Kenji Fukaya (Kyoto)
- Yoshiaki Maeda (Yokohama)
- Dusa McDuff (Stony Brook)
- Paul Seidel (MIT)
- Alan Weinstein (Berkeley)

1 Scientific description

The Hayashibara Forum was held on May 10-14 at MSRI as part of the 2009-2010 year long program on symplectic and contact geometry and topology. The Forum was run in cooperation with the Research Institute for Mathematical Sciences (RIMS), Kyoto University, which will host the follow-up meeting in November 2010.

In the past three decades, symplectic geometry, originally developed to describe classical mechanics, has undergone a rapid development with applications to3- and 4-dimensional topology via Floer theory, and has revealed profound connections between geometry and physics as in mirror symmetry. Noncommutative geometry attempts with some success to understand the "quantum universe" in a precise mathematical sense. Symplectic and noncommutative geometry are deeply connected through a circle of ideas motivated by quantum physics, although the precise nature of the linkage is not entirely clear.

One of the principal aims of the Hayashibara forum is to bring together researchers from geometry and physics, both to make a serious attempt to overcome conceptual barriers between experts and to expose these areas to younger researchers. A synthesis of ideas from geometry and physics should prove to be extremely powerful. This program is aimed at enhancing the understanding of the interaction between these subjects among researchers from both fields.

The conference included discussions on recent work with the explicit goal of furthering interactions between mathematicians and physicists. We anticipate an expanded interest in these interactions and the realization that experts and students in each field can indeed work in the other. To this end, this conference contained mini-course lectures aimed at increasing communication in mathematics and physics.

2 Highlights of the presentations

One striking feature of the workshop was the inclusion of three mini-course lectures aimed at increasing the interaction between mathematicians and physicists, and also to encourage young researchers to explore both fields.

The first lecturer, Yan Soibelman (Kansas), presented three lectures on an overview of his joint work with Maxim Kontsevich on motivic Donaldson-Thomas invariants for 3D Calabi-Yau categories. Soibelman presented two approaches, one based on the ideas of motivic integration, and the second based on the notion of cohomological Hall algebras.

The second mini-course lecturer was Dennis Auroux (MIT), who gave lectures on special Lagrangian torus fibrations and mirror symmetry. These lectures focused on the construction of mirror manifolds using special Lagrangian fibrations, with the Strominger-Yau-Zaslow conjecture as a starting point. The main goal was the construction of a mirror manifold to a Kähler manifold with effective anticanonical class, using a special Lagrangian torus fibration and enumerative geometry data (weighted counts of holomorphic discs). Auroux's first talk provided motivation for the SYZ conjecture and basic examples. In particular, he explained how Landau-Ginzburg models naturally arise in the non-Calabi-Yau setting, viewing the superpotential as a mirror counterpart to a Floer-theoretic obstruction. The main example is toric Fano varieties. In the second talk, Auroux presented a simple example of the wall-crossing phenomena arising in the non-toric case, to motivate "instanton corrections". Finally, he discussed joint work in progress with Mohammed Abouzaid and Ludmil Katzarkov on the extension of mirror symmetry to arbitrary hypersurfaces in toric varieties, by considering Lagrangian fibrations on blow-ups. Here the main examples are pairs of pants (and their higher-dimensional analogues) and higher-genus curves.

The third mini-course lecturer was Katrin Wehrheim (MIT), who gave lectures on two topics. The first topic, joint work with Chris Woodward, was a symplectic categorical approach to Lagrangian correspondences and holomorphic quilts, which allows them to define a symplectic category Symp whose morphisms are generalized Lagrangian correspondences. In monotone or exact settings, Symp extends to a 2-category whose 2-morphism spaces are Floer homology groups. This induces a functor from Symp to Donaldson-Fukaya type categories and functors between them. These algebraic structures arise naturally from holomorphic quilts and all proofs can be given by pictures and a fundamental "strip shrinking" isomorphism. The second topic was topological quantum field theories via the symplectic category. The symplectic 2-category provides a general machinery for constructing new topological invariants or TQFT's as functors Top $\to$ Cat from a "symplectization" Top $\to$ Symp of a topological category Top. To construct the latter, it suffices to associate smooth Lagrangian correspondences to "simple morphisms" (e.g. 3-cobordisms or tangles with one critical point) and to check that the Cerf moves (which connect equivalent decompositions into simple morphisms) correspond to embedded composition of Lagrangian correspondences.

The workshop included 12 plenary talks on recent research in various fields related our topics. James Simons (Renaissance Technologies) , who is famous for his work on Chern-Simons invariants, spoke on differential cohomology. The other talks covered topics in Floer theory, the Fukaya category, operator theory, and homotopy algebras from the mathematical and physical sides.

- Manabu Akaho (Tokyo Metropolitan University): Towards singular Lagrangian Floer theory
- Yong-Geun Oh (University of Wisconsin-Madison): Lagrangian Floer theory of toric manifolds and mirror symmetry
- Anton Kapuskin (Caltech) : Topological field theory and complex symplectic geometry
- Hiroshige Kajiura (Chiba University): On some deformations of the Fukaya category
- Hiroshi Oguri (Caltech/Tokyo University): Wall crossing seen by M-theory and Matrix theory
- Dmitry Tamarkin (Northwestern University): A Mmcro category for a symplectic manifolds
- Bruno Vallette (University of Nice): Homotopy algebra with operads
- Mana Aganagic (UC Berkeley): Wall crossing, quivers and dimers

- Tohru Eguchi (Yukawa Institute, Kyoto University): Entropy of manifolds with reduced holonomy
- Bertrand Eynard (Scalay) : Matrix model techniques in enumerative geometry

Yongbin Ruan (University of Michigan) gave an interesting talk on the Landau-Ginzburg/Calabi-Yau correspondence. A far reaching correspondence from physics suggests that the Gromov-Witten theory of a Calabi-Yau hypersurface in a weighted projective space (or more generally, a toric variety) can be computed by the singularity theory of its defining polynomial. Ruan presented some progress (jointly with Alessandro Chiodo) towards establishing this correspondence mathematically, as well as some surprising results and further speculations.

This workshop in MSRI will be followed by a meeting at RIMS, Kyoto University, with invited distinguished speakers including Yakov Eliashberg (Stanford University), Kenji Fukaya (Kyoto University), Ezra Getzler (Northwestern University), Alexander Givental (UC Berkeley), Ryzsard Nest (Copenhagen University), and Chris Woodward (UC Berkeley).

Symplectic Geometry, Noncommutative Geometry and Physics

May 10 to May 14, 2010, MSRI, Berkeley, CA, USA

Invited Speakers

First Name	Last Name	Current Institution
Mina	Aganagic	University of California, Berkeley
Manabu	Akaho	Tokyo Metropolitan University
Denis	Auroux	University of California
Tohru	Eguchi	Kyoto University, Yukawa Institute for Theoretical Physics
Bertrand	Eynard	University of British Columbia
Hiroshige	Kajiura	Chiba University
Anton	Kapustin	California Institute of Technology
Yong-Geun	Oh	University of Wisconsin
Hirosi	Ooguri	California Institute of Technology
Yongbin	Ruan	University of Michigan
James	Simons	Euclidean Capital LLC
Yan	Soibelman	Kansas State University
Dmitry	Tamarkin	Northwestern University
Bruno	Vallette	Université de Nice Sophia Antipolis
Katrin	Wehrheim	Massachusetts Institute of Technology

Symplectic Geometry, Noncommutative Geometry and Physics

May 10 to May 14, 2010, MSRI, Berkeley, CA, USA

Schedule

Monday May 10		
09:00AM - 10:00AM	Registration	
10:00AM - 10:45AM	Opening	
11:00AM - 12:00PM	Yan Soibelman	Motivic Donaldson-Thomas invariants and wall-crossing formulas (1)
12:00PM - 01:30PM	Lunch	
01:30PM - 02:30PM	James Simons	Remarks on Differential Cohomology
02:35PM - 03:35PM	Katrin Wehrheim	Lagrangian correspondences and holomorphic quilts
03:35PM - 04:15PM	Tea	
04:15PM - 05:15PM	Yong-Geun Oh	Lagrangian Floer theory of toric manifolds and mirror symmetry
Tuesday May 11		
09:30AM - 10:30AM	Manabu Akaho	Towards singular Lagrangian Floer theory
10:30AM - 11:00AM	Tea	
11:00AM - 12:00PM	Yan Soibelman	Motivic Donaldson-Thomas invariants and wall-crossing formulas (2)
12:00PM - 01:30PM	Lunch	
01:30PM - 02:30PM	Anton Kapustin	Topological field theory and complex symplectic geometry
02:35PM - 03:35PM	Katrin Wehrheim	A symplectic category - chain level version and symplectic applications
03:35PM - 04:15PM	Tea	
04:15PM - 05:15PM	Denis Auroux	Special Lagrangian torus fibrations and mirror symmetry (1)
Wednesday May 12		
09:00AM - 10:00AM	Hiroshige Kajiura	On some deformation of Fukaya category
10:00AM - 10:30AM	Tea	
10:30AM - 11:30AM	Yan Soibelman	Motivic Donaldson-Thomas invariants and wall-crossing formulas (3)
11:40AM - 12:40PM	Katrin Wehrheim	Topological quantum field theories via the symplectic category

Symplectic Geometry, Noncommutative Geometry and Physics
May 10 to May 14, 2010, MSRI, Berkeley, CA, USA

Thursday May 13		
09:30AM - 10:30AM	Hirosi Ooguri	Wall Crossing as Seen by M Theory and Matrix Models
10:30AM - 11:00AM	Tea	
11:00AM - 12:00PM	Denis Auroux	Special Lagrangian torus fibrations and mirror symmetry (2)
12:00PM - 01:30PM	Lunch	
01:30PM - 02:30PM	Dmitry Tamarkin	Microlocal category for a symplectic manifold
02:35PM - 03:35PM	Bertrand Eynard	Matrix model techniques in enumerative geometry
03:35PM - 04:15PM	Tea	
04:15PM - 05:15PM	Yongbin Ruan	Landau-Ginzburg/Calabi-Yau Correspondence
Friday May 14		
09:30AM - 10:30AM	Bruno Vallette	Homotopy algebra with operads
10:30AM - 11:00AM	Tea	
11:00AM - 12:00PM	Denis Auroux	Special Lagrangian torus fibrations and mirror symmetry (3)
12:00PM - 01:30PM	Lunch	
01:30PM - 02:30PM	Mina Aganagic	Wall Crossing, Quivers and Dimers
02:30PM - 03:00PM	Tea	
03:00PM - 04:00PM	Tohru Eguchi	Entropy of manifolds with reduced holonomy
04:00PM - 04:20PM	Closing	

Symplectic Geometry, Noncommutative Geometry and Physics

May 10 to May 14, 2010, MSRI, Berkeley, CA, USA

Officially Registered Participant

First Name	Last Name	Current Institution
Mina	Aganagic	University of California, Berkeley
Manabu	Akaho	Tokyo Metropolitan University
Lino	Amorim	University of Wisconsin
Denis	Auroux	University of California
Christopher	Beem	University of California
Mélanie	Bertelson	Université Libre de Bruxelles
Henrique	Bursztyn	Institute of Pure and Applied Mathematics (IMPA)
Santiago	Canez	University of California, Berkeley
Bianca	Cerchiai	Università di Milano
Sergey	Cherkis	Trinity College
Luis	Diogo	Stanford University
Tohru	Eguchi	Kyoto University, Yukawa Institute for Theoretical Physics
Yakov	Eliashberg	Stanford University
Tolga	Etgu	Koç University
John	Etnyre	Georgia Institute of Technology
Bertrand	Eynard	University of British Columbia
David	Farris	University of California, Berkeley
Joel	Fish	Stanford University
Kenji	Fukaya	Kyoto University
Penka	Georgieva	Stanford University
Grégory	Ginot	Université de Paris VI (Pierre et Marie Curie)
Viktor	Ginzburg	University of California, Santa Cruz
Roman	Golovko	University of Southern California
Vinicius	Gripp	University of California, Berkeley
Sonja	Hohloch	Stanford University
Theo	Johnson-Freyd	University of California
Burglind	Joricke	Institut des Hautes Études Scientifiques (IHES)
Hiroshige	Kajiura	Chiba University
ONO	Kaoru	Hokkaido University
Anton	Kapustin	California Institute of Technology
Shoshichi	Kobayashi	University of California, Berkeley
Yvette	Kosmann-Schwarzbach	École Polytechnique
Sangwook	Lee	Seoul National University
Jiayong	Li	University of Toronto
Yu-Shen	Lin	Harvard University
Jiang-Hua	Lu	University of Hong Kong
Yoshiaki	Maeda	Keio University
Alessia	Mandini	Technical University of Lisbon
Dusa	McDuff	Barnard College
Kentaro	Mikami	Akita University
Hitoshi	Moriyoshi	Nagoya University
Motohico	Mulase	University of California
Max	Murphy	Stanford University
Thomas	Murphy	Dept. of Mathematics, King's College London
Yu	Nakayama	University of California, Berkeley
Lenhard	Ng	Duke University
Yong-Geun	Oh	University of Wisconsin

Symplectic Geometry, Noncommutative Geometry and Physics

May 10 to May 14, 2010, MSRI, Berkeley, CA, USA

First Name	Last Name	Current Institution
Hiroshi	Ohta	Nagoya University
Hirosi	Ooguri	California Institute of Technology
Brett	Parker	Universität Zürich
James	Pascaleff	Massachusetts Institute of Technology
Jeremy	Pecharich	University of California--Irvine Medical Center
Tudor	Ratiu	École Polytechnique Fédérale de Lausanne (EPFL)
Steven	Rosenberg	Boston University
Yongbin	Ruan	University of Michigan
Helge	Ruddat	Universitat Freiburg, Germany
Jenny	Santoso	Universität Stuttgart
Pierre	Schapira	Université de Paris VI (Pierre et Marie Curie)
James	Simons	Euclidean Capital LLC
Aaron	Smith	University of Pennsylvania
Yan	Soibelman	Kansas State University
Daniel	Sternheimer	Keio University, Department of Mathematics
Piotr	Sulkowski	California Institute of Technology
Dmitry	Tamarkin	Northwestern University
Makiko	Tanaka	Science University of Tokyo
Bulent	Tosun	Georgia Insitute of Technology
Bruno	Vallette	Université de Nice Sophia Antipolis
Vera	Vertesi	Massachusetts Institute of Technology
Christophe	WACHEUX	Université de Rennes I
Katrin	Wehrheim	Massachusetts Institute of Technology
Alan	Weinstein	University of California
Chris	Wendl	Humboldt-Universität
Ping	Xu	Centre Universitaire de Luxembourg
Shilin	Yu	Penn State University
Marco	Zambon	Autonomous University of Madrid
Anton	Zeitlin	Yale University

Symplectic Geometry, Noncommutative Geometry and Physics

May 10 to May 14, 2010, MSRI, Berkeley, CA, USA

Officially Registered Participant Information

Participants		**76**

Gender		**76**
Male	75.00%	57
Female	19.74%	15
Declined to state	5.26%	4

Ethnicity*		**79**
White	51.90%	41
Asian	26.58%	21
Hispanic	2.53%	2
Pacific Islander	0.00%	0
Black	1.27%	1
Native American	1.27%	1
Declined to state	16.46%	13

* ethnicity specifications are not exclusive

Connections for Women:
Homology Theories of Knots and Links

January 21 to January 22, 2010

MSRI, Berkeley, CA, USA

Organizers:

Elisenda Grigsby* (Columbia)

Olga Plamenevskaya (SUNY/Stonybrook)

Katrin Wehrheim (MIT)

Parent Program:

Homology Theories of Knots and Links

REPORT ON THE MSRI WORKSHOP "HOMOLOGY THEORIES OF KNOTS AND LINKS: CONNECTIONS FOR WOMEN"
January 21-22, 2010

Organizers

- J. Elisenda Grigsby (Boston College)
- Olga Plamenevskaya (SUNY Stony Brook)
- Katrin Wehrheim (MIT)

1. Scientific description

In recent years, there has been exciting progress in low-dimensional topology related to the use of "categorified" invariants to study links (disjoint, smooth imbeddings of circles into S^3, considered modulo smooth isotopy):

(1) Heegaard-Floer link homology (due to Ozsváth-Szabó , Rasmussen), and
(2) Khovanov link homology (due to Khovanov).

These theories associate to a link an abstract, bigraded chain complex whose homology is a link invariant. The graded Euler characteristic of these bigraded homology groups yield classical polynomial invariants; moreover, the new "categorified" homology invariants contain substantially more topological information than their "classical" counterparts. In fact, both Khovanov and Heegaard Floer homology are powerful enough to detect the unknot, bound the complexity of certain smoothly imbedded surfaces in the 4–ball, and obstruct the existence of many exceptional surgeries on knots.

Because of the structural beauty of these new theories as well as their striking successes in addressing difficult problems in low-dimensional topology, younger mathematicians have flocked to the field. On the other hand, it has been somewhat difficult for junior researchers away from certain "research hubs" to learn about the core questions and mathematical philosophies driving research.

The primary aim of the *Connections for Women* workshop was to make Heegaard-Floer and Khovanov homology more accessible to newcomers by positioning the work in these areas within a broader context, focusing on applications to classical questions in low-dimensional topology and connections to contact and symplectic topology. Two secondary aims of the *Connections* workshop were to:

(1) showcase the range of current research activity in the field by female mathematicians, and
(2) provide opportunities for female mathematicians at various stages in their career to discuss mathematics with each other.

To accomplish these goals, the organizers asked four prominent female mathematicians–Shelly Harvey (Rice), Gordana Matic (Georgia), Effie Kalfagianni (MSU), and Dusa McDuff (Barnard)–to give survey talks on knot concordance, contact topology, quantum topology, and Floer homology during the morning sessions, emphasizing connections to the new knot homology theories. For the afternoon programs, we asked several junior female researchers–Keiko Kawamuro (Iowa), Joan Licata (Stanford), Heather Russell (LSU), and Vera Vertesi (MSRI)–to give hour-long research talks. In addition, the organizers invited Carmen Caprau (Cal State Fresno), Sinem Onaran (Oberwolfach), and Ina Petkova (Columbia) to give 30-minute research talks to round out the program. Kalfagianni was, unfortunately, unable to attend the workshop due to illness, so Elisenda Grigsby, one of the organizers, spoke in her place.

One highly successful feature of the *Connections* workshop was the large amount of interaction with the *Introductory* workshop. Members of our organizing team communicated frequently with members of the organizing team of the *Introductory* workshop to insure that our goals and activities complemented theirs. In addition, offers of financial support were well-coordinated to maximize attendance at both workshops, especially among junior researchers.

Overall, the workshop seems to have been a great success. Feedback from the attendees was extremely positive, many participants noting that the workshop really "set the stage" for the *Introductory* workshop by emphasizing the main points of contact between knot homology theories and other areas of low-dimensional topology. Without this motivation, it would have been more difficult to understand the importance of the theories discussed in detail during the *Introductory* workshop.

2. Highlights of presentations

The workshop opened with a talk by Elisenda Grigsby describing the algebraic structure of Khovanov and Heegaard-Floer homology, focusing very generally on the sense in which these theories provide "categorifications" of the classical Alexander and Jones polynomials. The purpose of this talk was to introduce the knot homology theories in general terms (leaving the details to the *Introductory* workshop) and give an idea of how understanding their relationship to the classical invariants has directed research in the field.

Dusa McDuff followed with an introduction to Floer theory. She noted that Heegaard Floer homology is a Lagrangian intersection Floer homology arising naturally from the data of a Heegaard splitting of a 3–manifold. She then went on to describe Morse homology from the geometric viewpoint, explaining how Floer theory can be viewed as an infinite dimensional analogue of classical Morse homology.

In the afternoon, Heather Russell spoke about Springer varieties, which appear both in the study of knot homologies and geometric representation theory. Building on work of Khovanov, who first noticed that the center of a certain ring H^n (which appears in the definition of a tangle invariant he defines) is isomorphic to the cohomology of the (n, n) Springer variety, Russell explained how to give a diagrammatic basis for this cohomology, leading to a beautiful description of the Bar-Natan skein module of the solid torus.

Keiko Kawamuro spoke about the dilatation invariant of pseudo-Anosov maps of surfaces and its relationship to the Alexander polynomial. Roughly speaking, the dilatation of a pseudo-Anosov map is the "stretching factor" associated to a foliation on the surface under the action of the map. In joint work with Joan Birman and Peter Brinkmann, she has analyzed how the matrix used to compute the dilatation factorizes over $\mathbb{Z}$ and what this says about the topology of the associated mapping torus.

To end the scientific portion of the first day of the workshop, Carmen Caprau discussed her universal $\mathfrak{sl}(2)$ foam cohomology, a bigraded invariant for oriented tangles generalizing Khovanov's invariant for links. She described the construction of the theory via webs and foams modulo local relations and presented some of its features (for example, its functoriality under tangle cobordisms).

After the talks, the participants held an informal panel discussion about academic issues, including those that might be of specific interest to women. The panelists included Shelly Harvey (Rice), Joanna Kania-Bartoszynska (NSF), Gordana Matic (University of Georgia), Dusa McDuff (Barnard), and Olga Plamenevskaya (Stony Brook). There was a brief disagreement among participants as to whether discrimination against women in mathematics is a current concern; however, most of the discussion was very friendly and included a lot of advice to younger mathematicians on topics such as job search, grant applications and research presentations. The panelists and more senior participants also answered a lot of questions about life in academia.

The day concluded with a very nice dinner, sponsored by MSRI, at a local Thai restaurant. The dinner provided an excellent opportunity for female participants to chat in an informal atmosphere.

The second day began with a beautiful talk by Shelly Harvey (Rice), who gave an overview of knot concordance results. She started with basic definitions, pictures, and a few classical theorems, and then described a few modern tools in knot concordance, including higher signatures, n-solvable filtrations, Heegaard Floer homology and Khovanov homology.

Gordana Matic (University of Georgia) gave the next talk, focusing on contact topology. She gave basic definitions and described the central questions in contact topology, then explained how to build Heegaard Floer contact invariants from an open book decomposition, and concluded with several applications.

In the afternoon, Vera Vertesi (MSRI) continued the discussion about contact topology, defining Legendrian and transverse knots in contact manifolds. She described several different invariants of these knots coming from Heegaard Floer homology, and then explained how these invariants are related.

Joan Licata (Stanford) also spoke on Legendrian knots, but from a quite different perspective. Her focus was on invariants, originating in contact homology and symplectic field theory, that take the form of a differential graded algebra. In certain simple cases, these invariants admit a combinatorial description; Joan discussed some known results for knots in S^3 and explained how to extend these ideas to knots in lens spaces.

Ina Petkova (Columbia) returned to the subject of knot concordance in her talk, discussing how the new bordered Floer homology technology of Lipshitz, Ozsváth, and D. Thurston can be used to give concordance information about cable knots.

The final talk of the conference was given by Cinem Onaran (Oberwolfach). She talked about the interplay between Legendrian knots and open book decompositions, outlining some interesting results concerning overtwisted contact structures and loose knots, and also explaining how Heegaard Floer invariants may be used to detect restrictions on the genus of open books compatible with certain contact structures.

Connections for Women: Homology Theories of Knots and Links

January 21 - 22, 2010 at MSRI, Berkeley, CA

Invited Speakers		
firstname	lastname	institutionname
Carmen	Caprau	California State University, Fresno
Eli	Grigsby	Boston College
Shelly	Harvey	Rice University
Keiko	Kawamuro	University of Iowa
Joan	Licata	Stanford University
Gordana	Matic	University of Georgia
Dusa	McDuff	Columbia University -- Bernard College
Sinem	Onaran	Mathematisches Forschungsinstitut Oberwolfach
Ina	Petkova	Columbia University
Heather	Russell	Louisiana State University
Vera	Vertesi	MSRI

Connections for Women: Homology Theories of Knots and Links

January 21 to January 22, 2010, MSRI, Berkeley, CA, USA

Schedule

Thursday January 21, 2010		
08:45AM - 09:00AM	Opening remarks	
09:00AM - 10:00AM	Eli Grigsby	Introduction to knot homology theories and categorification
10:00AM - 10:30AM	Break	
10:30AM - 11:30AM	Dusa McDuff	Introduction to Floer Theory
11:30AM - 01:30PM	Lunch break	
01:30PM - 02:30PM	Heather Russell	Springer varieties from the topological perspective
02:30PM - 03:00PM	Break	
03:00PM - 04:00PM	Keiko Kawamuro	Pseudo-Anosov maps and dilatations
04:15PM - 04:45PM	Carmen Caprau	The universal sl(2) foam cohomology
Friday January 22, 2010		
09:00AM - 10:00AM	Shelly Harvey	Knot and Link Concordance
10:00AM - 10:30AM	Break	
10:30AM - 11:30AM	Gordana Matic	Contact Invariants in Floer Homology
11:30AM - 01:30PM	Lunch break	
01:30PM - 02:30PM	Vera Vertesi	Knots in contact structures and Heegaard Floer homology
02:30PM - 03:00PM	Break	
03:00PM - 04:00PM	Joan Licata	Combinatorial invariants for Legendrian knots
04:15PM - 04:45PM	Ina Petkova	Cables of thin knots and bordered Heegaard Floer homology
05:00PM - 05:30PM	Sinem Onaran	Legendrian Knots and Open Book Decompositions

Connections for Women: Homology Theories of Knots and Links
January 21 to January 22, 2010, MSRI, Berkeley, CA, USA

Currently Available Videos

- **Eli Grigsby** , Introduction to knot homology theories and categorification
  January 21, 2010, 09:00 AM to 12:00 AM
- **Dusa McDuff** , Introduction to Floer Theory
  January 21, 2010, 10:30 AM to 11:30 AM
- **Heather Russell** , Springer varieties from the topological perspective
  January 2 ,2010, 01:30 PM to 02:30 PM
- **Keiko Kawamuro** , Pseudo-Anosov maps and dilatations
  January 21, 2010, 03:00 PM to 04:00 PM
- **Carmen Caprau** , The universal sl(2) foam cohomology
  January 21, 2010, 04:15 PM to 05:15 PM
- **Shelly Harvey** , Knot and Link Concordance
  January 22, 2010, 09:00 AM to 10:00 AM
- **Gordana Matic** , Contact Invariants in Floer Homology
  January 22, 2010, 10:30 AM to 11:30 AM
- **Vera Vertesi** , Knots in contact structures and Heegaard Floer homology
  January 22, 2010, 01:30 PM to 02:30 PM
- **Joan Licata** , Combinatorial invariants for Legendrian knots
  January 22, 2010, 03:00 PM to 04:00 PM
- **Ina Petkova** , Cables of thin knots and bordered Heegaard Floer homology
  January 22, 2010, 04:15 PM to 05:15 PM
- **Sinem Onaran** , Legendrian Knots and Open Book Decompositions
  January 22, 2010, 05:00 PM to 05:30 PM

Connections for Women: Homology Theories of Knots and Links

January 21 - 22, 2010 at MSRI, Berkeley, CA

Officially Registered Participants		
firstname	lastname	institutionname
Emi	Arima	University of California
Cheryl	Balm	Michigan State University
Bruno	Benedetti	TU Berlin
Eva	Berdajs	University of Ljubljana
Dorothy	Buck	Imperial College London
Carmen	Caprau	California State University, Fresno
Meredith	Casey	Georgia Institute of Technology
Caroline	Cocciardi	
Isabel	Darcy	University of Iowa
Silvia	De Toffoli	TU Berlin
Elizabeth	Denne	Smith College
Lyla	Fadali	University of California, San Diego
Eva	Feichtner	Universität Bremen
Lena	Folwaczny	University of Illinois, Chicago
Bridget	Franklin	Rice University
Agnès	Gadbled	Université de Neuchatel - Institut de Mathématiques
Whitney	George	University of Georgia
Julian	Gibbons	Imperial College London
Allison	Gilmore	Columbia University
Eli	Grigsby	Boston College
Megumi	Harada	McMaster University
Shelly	Harvey	Rice University
Kristen	Hendricks	Columbia University
Alexander	Hoffnung	University of California
Sonja	Hohloch	Tel Aviv University
Tara	Holm	Cornell University
Jen	Hom	University of Pennsylvania
Barbara	Jablonska	TU Berlin
Burglind	Jöricke	Institut des Hautes Études Scientifiques (IHES)
Efstratia	Kalfagianni	Michigan State University
Keiko	Kawamuro	University of Iowa
Mary	Kearney	Indiana University
Ailsa	Keating	Massachusetts Institute of Technology
Constance	Leidy	Wesleyan University
Joan	Licata	Stanford University
Gordana	Matic	University of Georgia
Aaron	Mazel-Gee	Brown University
Dusa	McDuff	Columbia University -- Bernard College
Heather	Molle	Franklin College
Damien	Mondragon	University of California, Berkeley
Marion	Moore	University of California, Davis
Danielle	O'Donnol	Department of Mathematics -MS 136
Sinem	Onaran	Mathematisches Forschungsinstitut Oberwolfach
Weiwei	Pan	Saint Mary's College of California
Elena	Pavelescu	Rice University
Ina	Petkova	Columbia University
Olga	Plamenevskaya	Stony Brook University
Candice	Price	University of Iowa

Connections for Women: Homology Theories of Knots and Links

January 21 - 22, 2010 at MSRI, Berkeley, CA

firstname	lastname	institutionname
Danielle	Rice	Portland State University
Dylan	Rupel	University of Oregon
Heather	Russell	Louisiana State University
Radmila	Sazdanovic	Serbian Academy of Sciences and Arts (SANU)
Inna	Scherbak	Tel Aviv University
Dave	Simpson	University of Illinois
Laura	Starkston	Harvard University
Cornelia	Van Cott	University of San Francisco
Vera	Vertesi	MSRI
Harold	Williams	University of California

Connections for Women: Homology Theories of Knots and Links

January 21 - 22, 2010 at MSRI, Berkeley, CA

Officially Registered Participants Information

Participants		**58**

Gender		**58**
Male	15.52%	9
Female	82.76%	48
Declined to state	1.72%	1

Ethnicity*		**62**
White	75.81%	47
Asian	12.90%	8
Hispanic	0.00%	0
Pacific Islander	0.00%	0
Black	1.61%	1
Native American	1.61%	1
Declined to state	8.06%	5

* ethnicity specifications are not exclusive

Mathematical Sciences Research Institute

Introductory Workshop:
Homology Theories of Knots and Links

January 25 to January 29, 2010

MSRI, Berkeley, CA, USA

Organizers:

Aaron Lauda (Columbia University)

Robert Lipshitz (Columbia University)

Dylan Thurston* (Columbia University)

Parent Program:

Homology Theories of Knots and Links

REPORT ON THE MSRI WORKSHOP "INTRODUCTORY WORKSHOP ON HOMOLOGY THEORIES OF KNOTS AND LINKS"

Organizers:

- Aaron Lauda (Columbia University)
- Robert Lipshitz (Columbia University)
- Dylan Thurston (Columbia University)

1. Scientific Description

The study of knot homologies is a young and active, subject in low-dimensional topology. Not to be confused with the classical subject of homology theories, the subject has two branches, one originating from gauge theory and symplectic geometry—the modern period began with the work of P. Ozsváth-Z. Szabó and J. Rasmussen on knot (Heegaard) Floer homology [5, 6], but many of the ideas can be traced back as far as A. Floer [2]—and the other form originating from quantum algebra and representation theory, leading to homology theories beginning with M. Khovanov's categorification of the Jones polynomial [3]. The latter approach exemplifies the philosophy of categorification introduced by Crane and Frenkel [1].

The main idea in the first branch is Floer homology, a particular type of infinite-dimensional Morse homology. Morally, this boils down to studying certain classes of natural partial differential equations on a cylinder over the knot complement. Several classes of partial differential equations are used, notable the J-holomorphic curve equation, as in Heegaard Floer homology, the Seiberg-Witten equations, as in monopole Floer homology, and the Yang-Mills equations, as in instanton Floer homology. Each of these has several variants. Remarkably, many different constructions seem to lead to equivalent invariants.

The second idea is more algebraic in flavor. This approach initially began with a categorification of the Kauffman bracket description of the Jones polynomial and was later generalized to other quantum invariants utilizing the skein theory descriptions of these invariants.

One of the main hopes for gaining a unified perspective on the subject is through the notion of categorification of quantum groups, in the sense of Khovanov-Lauda [4] and Rouquier [7]. Just like each type of Reshetikhin-Turaev invariant is determined by a quantum group and its representations, it is believed that each of these knot homology theories is governed by a categorified quantum groups and their representations.

In addition to their intrinsic interest, knot homology theories have many relations and applications to classical questions in low-dimensional topology.

1.1. **Goals of the workshop.** As noted above, the main techniques in the two branches of the field of knot homologies are quite different. Consequently, many researchers in one branch are largely ignorant of goals and techniques of the other. This is especially true for young researchers, like graduate and postdoctoral students. The main goal of the workshop was to start to ameliorate this situation, by introducing participants in one branch to the methods of the others.

At the same time, through a few higher-level research talks, the workshop sought to highlight a few recent developments in the field. One particular goal was to give young researchers a feel for what kinds of questions are interesting in the subjects.

Finally, the workshop sought to give relatively junior participants in the field the opportunity to present their understanding of, and work on, the subject. In this vein, only one of the speakers in the workshop—who had recently proved an exceptionally striking result—already had tenure.

2. Overview of Presentations

The bulk of the workshop consisted of three mini-courses, one on knot (Heegaard) Floer homology, one on Khovanov and Khovanov-Rozansky homology, and one on categorification of quantum groups.

The Floer homology lecture series attempted to present a broad picture of the Heegaard Floer package. To this end, it started with an overview of the subject by M. Hedden. (One of the organizers remembers hearing several graduate student participants discussing, in awe, how Hedden had managed to be both comprehensive and understandable.) Legendrian knots and grid diagrams play an increasingly important role in the field; L. Ng outlined this subject, and its connections with Heegaard Floer homology, in two clear talks. Rounding out the series, A. Juhász gave two talks introducing his sutured Floer homology, a remarkable structure and a key tool for many applications of knot Floer homology.

The Khovanov homology series started with two talks by S. Morrison on the basics. There is, by now, a standard, concrete, and not particularly illuminating way to present this material. Morrison shied away from that approach, instead giving a more conceptual (though more difficult) approach to the material. (The traditional approach was later explained by J. Bloom in one of the problem sessions.) This was followed by two talks of B. Webster on Khovanov-Rozansky homology, a subject often omitted from introductory discussions because of its increased technical detail. In particular, the machinery of matrix factorizations was introduced to describe Khovanov-Rozansky homology, a categorification of the HOMFLYPT polynomial. Many examples were discussed giving ample exposure to this more difficult machinery.

One of the most beautiful, and powerful, ideas in the categorification of quantum groups is the interplay with algebraic geometry. S. Cautis introduced the course on categorification with two lectures about instances of categorification in algebraic geometry. These lectures were followed by lectures of A. Lauda on diagrammatic categorification of quantum groups. (The organizers had hoped to have C. Stroppel speak on this subject, as well, but discovered at the last minute that she was unable to attend; we were grateful that Lauda was able to speak in her place.)

The lecture series on categorification helped spark a number of interesting mathematical conversations after the workshop ended. These included discussions between S. Cautis, A. Licata, R. Lipshitz, P. Ozsváth and D. Thurston on the existence of quantum $\mathfrak{gl}(1,1)$-actions in bordered Floer homology, and of J. Grigsby, C. Stroppel and S. Wehrli on relationships between the Khovanov-Seidel categorical braid group action and sutured / bordered (Heegaard) Floer homology. Of these, Cautis, Licata, Stroppel and Wehril are primarily workers in categorification (algebra), while Grigsby, Lipshitz, Ozsváth and Thurston work mainly in Floer homology (analysis)—so the workshop really did lead to meaningful interaction between the two halves.

In addition to the three courses, there were research talks by Licata on the work of Chuang and Rouquier applying categorical $\mathfrak{sl}(2)$-actions to classical problems in representation theory of the symmetric group; Webster on categorification of Reshetikhin-Turaev invariants; Grigsby on the relationship between sutured Khovanov homology and sutured Floer homology; and V. Vertesi on the classification of Legendrian and transverse twist knots. There was also a special research talk by T. Mrowka, on his recent proof, with P. Kronheimer, that Khovanov homology detects the unknot. (This breakthrough was made possible by relating Khovanov homology to a particular instanton homology theory—another instance of unification between the two halves of the field. Previous results along these lines had been obtained by Grigsby-Wehrli and Hedden.) Finally, there was also an Evans lecture related to the topic of the workshop by G. Matic, on the contact invariant in Heegaard Floer homology.

As an unusual feature of the workshop, speakers were asked to distribute exercises related to the material of their lectures. There were daily problem sessions during the workshop, on each of the three course topics, to discuss these problem sets and generally facilitate discussion of the material. Anecdotally, the problem sets were an unqualified success: in addition to helping the participants learn the material, they also helped the speakers to aim their talks at appropriate levels. The problem sessions were also a success, though, predictably, the palpable enthusiasm for them at the beginning of the week waned slightly by the end. Problem sessions were led by J. Bloom, A. Ellis, A. Lauda, A. Levine, V. Vertesi and Q. You.

References

[1] L. Crane and I. B. Frenkel. Four-dimensional topological quantum field theory, Hopf categories, and the canonical bases. *J. Math. Phys.*, 35(10):5136–5154, 1994.

[2] Andreas Floer. Instanton homology and Dehn surgery. In *The Floer memorial volume*, number 133 in Progr. Math., pages 77–97. Birkhäuser, 1995.

[3] Mikhail Khovanov. A categorification of the Jones polynomial. *Duke Math. J.*, 101(3):359–426, 2000.

[4] Mikhail Khovanov and Aaron D. Lauda. A diagrammatic approach to categorification of quantum groups. I. *Represent. Theory*, 13:309–347, 2009.
[5] Peter S. Ozsváth and Zoltán Szabó. Holomorphic disks and knot invariants. *Adv. Math.*, 186(1):58–116, 2004.
[6] Jacob Rasmussen. *Floer homology and knot complements*. PhD thesis, Harvard University, 2003.
[7] R. Rouquier. 2-Kac-Moody algebras, 2008. arXiv:0812.5023.

Introductory Workshop: Homology Theories of Knots and Links
January 25 to 29, 2010 at MSRI, Berkeley, CA

Invited Speakers

firstname	lastname	institutionname
Sabin	Cautis	Columbia University
Eli	Grigsby	Boston College
Matthew	Hedden	Michigan State University
Andras	Juhasz	University of Cambridge
Aaron	Lauda	Columbia University
Anthony	Licata	Stanford University
Gordana	Matic	University of Georgia
Scott	Morrison	University of California, Berkeley
Tomasz	Mrowka	Massachusetts Institute of Technology
Lenhard	Ng	Duke University
Vera	Vertesi	MSRI
Ben	Webster	Massachusetts Institute of Technology

Connections for Women: Homology Theories of Knots and Links
January 21 to January 22, 2010, MSRI, Berkeley, CA, USA

Schedule		
Monday January 25, 2010		
09:30AM - 10:30AM	Matthew Hedden	Heegaard Floer Homology I
10:30AM - 11:00AM	Coffee, tea in the atrium	
11:00AM - 12:00PM	Scott Morrison	Khovanov Homology I
12:00PM - 01:30PM	Lunch	
01:30PM - 02:30PM	Sabin Cautis	Categorical quantum group actions in geometry, I
02:30PM - 03:30PM	Problem Sessions	
03:30PM - 04:00PM	Coffee, tea in the atrium	
04:00PM - 05:00PM	Evans lecture: Gordana Matic	
Tuesday January 26, 2010		
09:30AM - 10:30AM	Matthew Hedden	Heegaard Floer Homology II
10:30AM - 11:00AM	Coffee, tea in the atrium	
11:00AM - 12:00PM	Lenhard Ng	Legendrian Knots I
12:00PM - 01:30PM	Lunch	
01:30PM - 02:30PM	Problem Sessions	
02:30PM - 03:30PM	Scott Morrison	Khovanov Homology II
03:30PM - 04:00PM	Coffee, tea in the atrium	
04:00PM - 05:00PM	Sabin Cautis	Categorical quantum group actions in geometry, II
Wednesday January 27, 2010		
09:30AM - 10:30AM	Andras Juhasz	Sutured Floer Homology I
10:30AM - 11:00AM	Coffee, tea in the atrium	
11:00AM - 12:00PM	Lenhard Ng	Legendrian knots II
12:00PM - 01:30PM	Lunch	
01:30PM - 02:30PM	Problem Session	
02:30PM - 03:30PM	Ben Webster	Khovanov-Rozansky Homology
03:30PM - 04:00PM	Coffee, tea in the atrium	
04:00PM - 05:00PM	Tomasz Mrowka	Introduction to Instanton Floer Homology
Thursday January 28, 2010		
09:30AM - 10:30AM	Andras Juhasz	Sutured Floer Homology II
10:30AM - 11:00AM	Coffee, tea in the atrium	
11:00AM - 12:00PM	Ben Webster	Khovanov-Rozansky Homology II

Connections for Women: Homology Theories of Knots and Links
January 21 to January 22, 2010, MSRI, Berkeley, CA, USA

12:00PM - 01:30PM	Lunch	
01:30PM - 02:30PM	Problem Sessions	
02:30PM - 03:30PM	Aaron Lauda	A categorification of quantum sl(2)
03:30PM - 04:00PM	Coffee, tea in the atrium	
04:00PM - 05:00PM	Anthony Licata	Applications of sl(2) Categorification
Friday January 29, 2010		
09:30AM - 10:30AM	Aaron Lauda	Diagrammatic categorification of quantum groups II
10:30AM - 11:00AM	Coffee, tea in the atrium	
11:00AM - 12:00PM	Ben Webster	Categorification of Reshetikhin-Turaev Invariants.
12:00PM - 01:30PM	Lunch	
01:30PM - 02:30PM	Eli Grigsby	A connection between Khovanov homology and Heegaard Floer homology
02:30PM - 03:00PM	Coffee, tea in the atrium	
03:00PM - 04:00PM	Vera Vertesi	Legendrian and Transverse Classification of twist knots

Connections for Women: Homology Theories of Knots and Links
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Currently Available Videos

- **Matthew Hedden** , Heegaard Floer Homology I
  January 25,2010, 09:30 AM to 10:30 AM
- **Scott Morrison, Scott Morrison** , Khovanov Homology I
  January 25,2010, 11:00 AM to 12:00 PM
- **Sabin Cautis** , Categorical quantum group actions in geometry, I
  January 25,2010, 01:30 PM to 02:30 PM
- **Matthew Hedden** , Heegaard Floer Homology II
  January 26,2010, 09:30 AM to 10:30 AM
- **Lenhard Ng** , Legendrian Knots I
  January 26,2010, 11:00 AM to 12:00 PM
- **Scott Morrison** , Khovanov Homology II
  January 26,2010, 02:30 PM to 03:30 PM
- **Sabin Cautis** , Categorical quantum group actions in geometry, II
  January 26,2010, 04:00 PM to 05:00 PM
- **Andras Juhasz** , Sutured Floer Homology I
  January 27,2010, 09:30 AM to 10:30 AM
- **Lenhard Ng** , Legendrian knots II
  January 27,2010, 11:00 AM to 12:00 PM
- **Ben Webster** , Khovanov-Rozansky Homology I
  January 27,2010, 02:30 PM to 03:30 PM
- **Tomasz Mrowka** , Introduction to Instanton Floer Homology
  January 27,2010, 04:00 PM to 05:00 PM
- **Andras Juhasz** , Sutured Floer Homology II
  January 28,2010, 09:30 AM to 10:30 AM
- **Ben Webster** , Khovanov-Rozansky Homology II
  January 28,2010, 11:00 AM to 12:00 PM
- **Aaron Lauda** , A categorification of quantum sl(2)
  January 28,2010, 02:30 PM to 02:30 PM
- **Anthony Licata** , Applications of sl(2) Categorification
  January 28,2010, 04:00 PM to 05:00 PM
- **Aaron Lauda** , Diagrammatic categorification of quantum groups II
  January 29,2010, 09:30 AM to 10:30 AM
- **Ben Webster** , Knot Homology for Quantum Invariants Through Pictures
  January 29,2010, 11:00 AM to 12:00 PM
- **Eli Grigsby** , A connection between Khovanov homology and Heegaard Floer homology
  January 29,2010, 01:30 PM to 02:30 PM
- **Vera Vertesi** , Legendrian and Transverse Classification of twist knots.
  January 29,2010, 03:00 PM to 04:00 PM

Introductory Workshop: Homology Theories of Knots and Links

January 25 to 29, 2010 at MSRI, Berkeley, CA

Officially Registered Participants

firstname	lastname	institutionname
Mohammed	Abouzaid	Massachusetts Institute of Technology
Mio	Alter	University of Texas - Austin
Emi	Arima	University of California, Davis
Denis	Auroux	University of California
Cheryl	Balm	Michigan State University
Bruno	Benedetti	TU Berlin
Eva	Berdajs	University of Ljubljana
Dorothy	Buck	Imperial College London
Carmen	Caprau	California State University, Fresno
Sabin	Cautis	Columbia University
William	Cavendish	Princeton University
Adam	Clay	University of British Columbia
Moshe	Cohen	Louisiana State University
Isabel	Darcy	University of Iowa
Silvia	De Toffoli	TU Berlin
Elizabeth	Denne	Smith College
Alan	Diaz	Georgia Institute of Technology
Tudor Dan	Dimofte	California Institute of Technology
Margaret	Doig	Princeton University
Sean	Droms	University of Virginia
Alexander	Ellis	Columbia University
Ana	Evans	University of Virginia
Lyla	Fadali	University of California, San Diego
Lena	Folwaczny	University of Illinois at Chicago
Bridget	Franklin	Rice University
David	Gabai	Princeton University
Whitney	George	University of Georgia
Julian	Gibbons	Imperial College London
Allison	Gilmore	Columbia University
Chad	Giusti	University of Oregon
Frederick	Goodman	University of Iowa
Eli	Grigsby	Boston College
Brandy	Guntel	Department of Mathematics
Owen	Gwilliam	Northwestern University
Megumi	Harada	McMaster University
Matthew	Hedden	Michigan State University
Matthew	Hogancamp	University of Virginia
Sonja	Hohloch	Tel Aviv University
Jen	Hom	University of Pennsylvania
Peter	Horn	Columbia University
Jim	Howie	University of Melbourne
Yang	Huang	University of Southern California
Thomas	Jaeger	Michigan State University
Burglind	Jöricke	Institut des Hautes Études Scientifiques (IHES)
Andras	Juhasz	University of Cambridge
Aaron	Kaestner	University of Illinois
Malgorzata	Kalabis	Silesia Technical University
Amey	Kaloti	Georgia Institute of Technology

Introductory Workshop: Homology Theories of Knots and Links
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firstname	lastname	institutionname
Will	Kazez	University of Georgia
Mary	Kearney	Indiana University
Ailsa	Keating	Massachusetts Institute of Technology
Aleksandra	Kowalik	Silesia Technical University
Robin	Koytcheff	Department of Mathematics, Stanford University
Daniel	Krasner	University of California
Aaron	Lauda	Columbia University
Ik Jae	Lee	Kansas State University
Constance	Leidy	Wesleyan University
John	Lesieutre	Massachusetts Institute of Technology
Anthony	Licata	Stanford University
Tye	Lidman	University of California
Gordana	Matic	University of Georgia
Jason	McGibbon	University of Massachusetts
Jeffrey	Meier	University of Texas
Damien	Mondragon	University of California, Berkeley
Allison	Moore	University of Texas
Scott	Morrison	University of California, Berkeley
Hugh	Morton	University of Liverpool
Tomasz	Mrowka	Massachusetts Institute of Technology
Lenhard	Ng	Duke University
Danielle	O'Donnol	Department of Mathematics -MS 136
Sinem	Onaran	Mathematisches Forschungsinstitut Oberwolfach
Weiwei	Pan	Saint Mary's College of California
James	Pascaleff	Massachusetts Institute of Technology
Ina	Petkova	Columbia University
Olga	Plamenevskaya	State University of New York (SUNY)
Candice	Price	University of Iowa
You	Qi	Columbia University
Bela	Racz	Princeton University
Danielle	Rice	Portland State University
Dale	Rolfsen	University of British Columbia
David	Rose	Duke University
Rory	Rother	University of Texas
Dylan	Rupel	University of Oregon
Heather	Russell	Louisiana State University
Joshua	Sabloff	Haverford College
Radmila	Sazdanovic	Serbian Academy of Sciences and Arts (SANU)
Inna	Scherbak	Tel Aviv University
Cotton	Seed	Princeton University
Yuan	Shen	Northwestern University
Dave	Simpson	University of Illinois
Steven	Sivek	Massachusetts Institute of Technology
Eric	Staron	Department of Mathematics
Catharina	Stroppel	Universität Bonn
Hiroaki	Tanaka	Northwestern University
Dylan	Thurston	Barnard College
Bulent	Tosun	Georgia Insitute of Technology
Anh	Tran	Georgia Institute of Technology

Introductory Workshop: Homology Theories of Knots and Links
January 25 to 29, 2010 at MSRI, Berkeley, CA

firstname	lastname	institutionname
Eamonn	Tweedy	University of California
Jeremy	Van Horn-Morris	American Institute of Mathematice (AIM)
Mikael	Vejdemo-Johansson	Stanford University
David	Vela-Vick	Columbia University
Vera	Vertesi	MSRI
Thao	Vuong	Georgia Institute of Technology
Kangkang	Wang	Georgia Institute of Technology
Ben	Webster	Massachusetts Institute of Technology
Harold	Williams	University of California
Michael	Williams	University of California
Benjamin	Wilson	University of California, San Diego
Rumen	Zarev	Columbia University

Introductory Workshop: Homology Theories of Knots and Links

January 25 to 29, 2010 at MSRI, Berkeley, CA

Officially Registered Participant Information

Participants		109

Gender		109
Male	62.39%	68
Female	35.78%	39
Declined to state	1.83%	2

Ethnicity*		114
White	73.68%	84
Asian	14.91%	17
Hispanic	1.75%	2
Pacific Islander	0.00%	0
Black	1.75%	2
Native American	0.88%	1
Declined to state	7.02%	8

* ethnicity specifications are not exclusive

MSRI Mathematical Sciences Research Institute

Research Workshop: Homology Theories of Knots and Links

March 15 to March 19, 2010

MSRI, Berkeley, CA, USA

Organizers:

Mikhail Khovanov (Columbia University)

Peter S. Ozsváth* (Columbia University)

Peter Teichner (UC Berkeley)

Parent Program:

Homology Theories of Knots and Links

REPORT ON THE MSRI WORKSHOP "HOMOLOGY THEORIES OF KNOTS AND LINKS"

Organizers

- Mikhail Khovanov (Columbia University)
- Peter Ozsváth (Columbia University)
- Peter Teichner (UC/Berkeley)

1. Scientific description

Link homology is a new source tools for studying low-dimensional phenomena. Although its goal is to explore the topology of familiar low-dimensional objects – knots, links, and indeed three- and four-manifolds – this rapidly-developing subject draws on many seemingly unrelated branches of mathematics. The field is driven primarily by three currents in mathematics: representation theory, gauge theory, and symplectic geometry. These three currents have lead, respectively, to Khovanov homology and other "categorifications"; forms of gauge-theoretic Floer homology including instanton Floer homology (using anti-self-dual connections), and more recently Floer homology for Seiberg-Witten monopoles; and finally, Heegaard Floer homology, along with its other variants for knots, links, and sutured manifolds.

This new discipline is at a critical moment in its development. Categorification has seen a broad expansion as a subject. It is now solidly linked to homological algebra of rings and differential graded rings. Relations have been found between link homology and algebraic geometry, including derived categories of sheaves on suitable quiver varieties and convolution varieties in affine Grassmannians. A more direct connection between categorification and the Langlands program is likely to be found in the near future.

Various calculational techniques have rendered aspects of Heegaard Floer homology to be combinatorially describable (a goal which has so far eluded its gauge-theoretic predecessors). Various relationships have been discovered relating categorifications with their more geometrically-defined cousins (typically formulated as spectral sequence from categorified invariants to gauge-theoretic or symplectically defined invariants). Finally, continuing the thread unifying gauge theory and symplectic geometry initiated by Taubes (in his proof that Seiberg-Witten invariants count certain Gromov invariants), the close relationship between Heegaard Floer homology and Seiberg-Witten theory is well on its way from being a conjecture to a theorem. In addition to these various exciting developments within the subject of link homology, the subject continues to interact with classical questions in low-dimensinal topology, shedding new light on and solving old problems.

The aim of this workshop was both to explore progress within these three streams, but also to study their interactions.

Owing in part to its richness and its promise as a new tool in low-dimensional topology, link homology has attracted a large number of talented young mathematicians. A conference bringing together these young researchers from all over the world, along with the leaders in the field, proved to be beneficial both to the professional development of those young researchers, and to to the development of the subject.

2. Highlights from the workshop

The workshop started with a focus on developments within categorification.

Ben Webster talked about his recent remarkable categorification of Reshetikhin-Turaev invariants of links and tangles associated to arbitrary simple Lie algebras. To a simple Lie algebra and a tensor product of its irreducible representations he assigns a ring categorifying this tensor product, and to a tangle - a functor between derived categories of modules over these rings. On the Grothendieck group these functors descend to Reshetikhin-Turaev invariants. His construction utilizes an earlier work of Khovanov and Lauda on categorification of positive halves of quantized universal enveloping algebras and should have far-reaching implications for the development of representation theory and low-dimensional topology.

Lev Rozansky explained his research with Anton Kapustin on a novel structure associated to a holomorphic symplectic manifold which appears to be a sort of categorification of the Fukaya-Floer category of the manifold restricted to holomorpic lagrangian submanifolds. Catharina Stroppel talked about her joint work with Igor Frenkel and Joshua Sussan on categorification of 3j-symbols. The goal here is to categorify the entire fine structure of representation theory of quantum sl(2) paving the way for categorification of Witten-Reshetikhin-Turaev invariants of 3-manifolds. Aaron Lauda gave an overview of his categorification of the idempotented form of quantum sl(2). Lauda's 2-category is presented via an amazing graphical calculus incorporating cohomology of flag varieties, isotopies of planar diagrams and biadjoint functors. It has basic fundamental structure and is expected to act on all interesting categorifications of quantum sl(2) representations. Pedro Vaz explained a kind of dimensional reduction allowing to encode part of 3-dimensional sl(N) foam theory (which gives rise to categorification of the HOMFLYPT polynomial) via 2-dimensional objects, which happen to give Elias-Khovanov diagrammatics for the Soergel category, a categorification of the Hecke algebra. Louis Kauffman spoke about possible applications of link homology to quantum computation.

There were several talks which dealt with applications of new techniques to older questions in topology. In this vein, Joshua Greene (Columbia) presented some exciting recent developments in the lens space realization problem, enumerating all lens spaces which are obtained as surgeries on knots in the three-sphere. This question first arose in a purely classical context (Dehn surgeries on knots in the three-sphere), but its solution uses tools from both Heegaard Floer homology and Donaldson theory (gauge theory). In a different classical application of the theory, Sucharit Sarkar discussed how sutured Floer homology can be used to distinguish different Seifert surfaces for a fixed knot in S^3. John Baldwin discussed how an algebraic structure in link Floer homology – a comultiplication – gives infinitely many new examples of prime link types which are not transversally simple.

Other talks focused on new developments within the various fields. In this spirit, Robert Lipshitz (Columbia) presented aspects of *bordered Floer homology*, a new invariant for three-manifolds with boundary (defined in joint work with Ozsváth and Thurston) which is closely connected to Heegaard Floer homology. Specifically, he discussed how knot Floer homology could be obtained as the Hochschild homology groups of bimodules defined in the theory. Bordered Floer homology was further discussed by Denis Auroux, in a lecture where he gave an interpretation of this new invariant in terms of Fukaya categories of the symmetric product of a Riemann surface. In a related direction, Tim Perutz discussed an invariant counting Lagrangian correspondences which is expected to give another Heegaard-Floer theoretic invariant for three-manifolds with boundary.

Jacob Rasmussen (Cambridge) described the relationship between the maps induced by contact structures in sutured Floer homology, and four-manifold invariants gotten by counting pseudo-holomorphic triangles.

One trend within Heegaard Floer homology is its combinatorialization. Talks which explored this included lectures by András Stipsicz (Rényi Institute, Budapest) and Zoltán Szabó (Princeton) focusing on a combinatorial formulation of a version of Heegaard Floer homology, and its Similarly, Ciprian Manolescu discussed a combinatorial approach to Heegaard Floer homology (joint with Ozsváth and Thurston), giving a calculation of the invariants for surgeries on links, in terms of grid diagrams for those links. relationship with Heegaard decompositions.

On Thursday, the program was complemented significantly by a colloquium talk by Mikhail Khovanov. He spoke about his joint with with Aaron Lauda on diagrammatic categorification of quantum deformations of universal enveloping algebras of Kac-Moody Lie algebras.

Another very exciting development in the subject which spans two of the above named streams (though draws some impetus from the third, as well), is Kronheimer and Mrowka's theorem stating that Khovanov homology detects the unknot. This result can be thought of as a “categorification” of a famous conjecture of Jones (that the Jones polynomial detects the unknot). Both Tomasz Mrowka and Peter Kronheimer gave talks about this new theorem. Elisenda Grigsby spoke about her related joint work with Wehrli connecting sutured Floer homology and versions of Khovanov homology.

Yi-Jen Lee spoke of her joint work with Cagathay Kutluhan and Clifford Taubes which, combined with earlier work of Taubes and constructions of Michael Hutchings, may lead ultimately to a proof of the equivalence of three important theories: Seiberg-Witten theory, embedded contact homology, and Heegaard Fleor homology.

Research Workshop: Homology Theories of Knots and Links

March 15 - 19, 2010 at MSRI, Berkeley, CA

Invited Speakers

firstname	lastname	institutionname
Denis	Auroux	University of California
John	Baldwin	Princeton University
Joshua	Greene	Columbia University
Eli	Grigsby	Boston College
Louis	Kauffman	University of Illinois
Peter	Kronheimer	Harvard University
Aaron	Lauda	Columbia University
Yi-Jen	Lee	Purdue University
Robert	Lipshitz	Columbia University
Ciprian	Manolescu	University of California, Los Angeles
Tomasz	Mrowka	Massachusetts Institute of Technology
Tim	Perutz	University of Texas
Jacob	Rasmussen	Cambridge University
Lev	Rozansky	University of North Carolina
Sucharit	Sarkar	Columbia University
András	Stipsicz	Hungarian Academy of Sciences
Catharina	Stroppel	Universität Bonn
Zoltan	Szabo	Princeton University
Pedro	Vaz	Technical University of Lisbon
Ben	Webster	Massachusetts Institute of Technology

Research Workshop:
Homology Theories of Knots and Links
March 15 to March 19, 2010, MSRI, Berkeley, CA, USA

Schedule

Monday March 15, 2010		
09:30AM - 10:30AM	Lev Rozansky	A 2-category associated with a holomorphic symplectic manifold (See Abstract)
10:30AM - 11:00AM	Tea	
11:00AM - 12:00PM	Catharina Stroppel	Categorification of coloured Jones and 3j-symbols (See Abstract)
12:00PM - 02:00PM	Lunch	
02:00PM - 03:00PM	Aaron Lauda	A categorification of quantum sl2 (See Abstract)
03:00PM - 03:30PM	Tea	
03:30PM - 04:30PM	Pedro Vaz	The diagrammatic Soergel category and sl(N)-foams (See Abstract)
Tuesday March 16, 2010		
09:30AM - 10:30AM	Robert Lipshitz	Hochschild homology via time dilation (See Abstract)
10:30AM - 11:00AM	Tea	
11:00AM - 12:00PM	Joshua Greene	The lens space realization problem (See Abstract)
12:00PM - 02:00PM	Lunch	
02:00PM - 03:00PM	András Stipsicz	Topological approach to Heegaard Floer homology I
03:00PM - 03:30PM	Tea	
03:30PM - 04:30PM	Zoltan Szabo	A topological approach to Heegaard Floer homology, II
Wednesday March 17, 2010		
09:30AM - 10:30AM	Louis Kauffman	Topological Quantum Information, Khovanov Homology and the Jones Polynomial (See Abstract)
10:30AM - 11:00AM	Tea	
11:00AM - 12:00PM	Ben Webster	Categorification of quantum groups and quantum knot invariants (See Abstract)
12:00PM - 02:00PM	Lunch	
02:00PM - 03:00PM	Jacob Rasmussen	Holomorphic triangles and maps induced by contact structures (See Abstract)
03:00PM - 03:30PM	Tea	
03:30PM - 04:30PM	Tim Perutz	Lagrangian correspondences and invariants for 3-manifolds with boundary (See Abstract)
Thursday March 18, 2010		
09:30AM - 10:30AM	Ciprian Manolescu	A combinatorial approach to Heegaard Floer invariants

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		(See Abstract)
10:30AM - 11:00AM	Tea	
11:00AM - 12:00PM	Sucharit Sarkar	Sutured Floer homology and minimal genus Seifert surfaces (See Abstract)
12:00PM - 01:00PM	Lunch	
01:00PM - 02:00PM	John Baldwin	Comultiplication in link Floer homology and transversely non-simple links (See Abstract)
02:00PM - 02:30PM	Tea	
02:30PM - 03:30PM	Tomasz Mrowka	The Unoriented Skein Relation for Instanton Knot Floer homology (See Abstract)
04:10PM - 05:00PM	UCB Mathematics Department Colloquium: Mikhail Khovano (See Abstract)	
Friday March 19, 2010		
09:30AM - 10:30AM	Denis Auroux	Fukaya categories of symmetric products and bordered Heegaard-Floer homology (See Abstract)
10:30AM - 11:00AM	Tea	
11:00AM - 12:00PM	Eli Grigsby	On sutured Khovanov homology and sutured Floer homology (See Abstract)
12:00PM - 02:00PM	Lunch	
02:00PM - 03:00PM	Yi-Jen Lee	"Filtered Seiberg-Witten Floer homologies with "almost harmonic" perturbations (See Abstract)
03:00PM - 03:30PM	Tea	
03:30PM - 04:30PM	Peter Kronheimer	From Khovanov homology to instanton homology for knots (See Abstract)

Research Workshop:
Homology Theories of Knots and Links
March 15 to March 19, 2010, MSRI, Berkeley, CA, USA

Currently Available Videos

- **Tim Perutz** , A 2-category associated with a holomorphic symplectic manifold *March 15,2010, 09:30 AM to 10:30 AM*
- **Catharina Stroppel** , Categorification of coloured Jones and 3j-symbols *March 15,2010, 11:00 AM to 12:00 PM*
- **Aaron Lauda** , A categorification of quantum sl2 *March 15,2010, 02:00 PM to 03:00 PM*
- **Pedro Vaz** , The diagrammatic Soergel category and sl(N)-foams *March 15,2010, 03:30 PM to 04:30 PM*
- **Robert Lipshitz** , Hochschild homology via time dilation *March 16,2010, 09:30 AM to 10:30 AM*
- **Joshua Greene** , The lens space realization problem *March 16,2010, 11:00 AM to 12:00 PM*
- **András Stipsicz** , Topological approach to Heegaard Floer homology I *March 16,2010, 02:00 PM to 03:00 PM*
- **Zoltan Szabo** , A topological approach to Heegaard Floer homology, II *March 16,2010, 03:30 PM to 04:30 PM*
- **Louis Kauffman** , Topological Quantum Information, Khovanov Homology and the Jones Polynomial *March 17,2010, 09:30 AM to 10:30 AM*
- **Benjamin Webster** , Categorification of quantum groups and quantum knot invariants *March 17,2010, 11:00 AM to 12:00 PM*
- **Jacob Rasmussen** , Holomorphic triangles and maps induced by contact structures *March 17,2010, 02:00 PM to 03:00 PM*
- **Tim Perutz** , Lagrangian correspondences and invariants for 3-manifolds with boundary *March 17,2010, 03:30 PM to 04:30 PM*
- **Ciprian Manolescu** , A combinatorial approach to Heegaard Floer invariants *March 18,2010, 09:30 AM to 10:30 AM*
- **Sucharit Sarkar** , Sutured Floer homology and minimal genus Seifert surfaces *March 18,2010, 11:00 AM to 12:00 PM*
- **John Baldwin** , Comultiplication in link Floer homology and transversely non-simple links *March 18,2010, 01:00 PM to 02:00 PM*
- **Tomasz Mrowka** , The Unoriented Skein Relation for Instanton Knot Floer homology *March 18,2010, 02:30 PM to 03:30 PM*
- **Denis Auroux** , Fukaya categories of symmetric products and bordered Heegaard-Floer homology *March 19,2010, 09:30 AM to 10:30 AM*
- **Eli Grigsby** , On sutured Khovanov homology and sutured Floer homology *March 19,2010, 11:00 AM to 12:00 PM*
- **Yi-Jen Lee** , "Filtered Seiberg-Witten Floer homologies with "almost harmonic" perturbations *March 19,2010, 02:00 PM to 03:00 PM*
- **Peter Kronheimer** , From Khovanov homology to instanton homology for knots *March 19,2010, 03:30 PM to 04:30 PM*

Research Workshop: Homology Theories of Knots and Links

March 15 - 19, 2010 at MSRI, Berkeley, CA

Officially Registered Participants

firstname	lastname	institutionname
Jiro	Adachi	Hokkaido University
Denis	Auroux	University of California
John	Baldwin	Princeton University
Stefan	Behrens	Max-Planck-Institut für Mathematik
Christian	Blanchet	Université de Paris VII (Denis Diderot)
Jonathan	Bloom	Columbia University
Maciej	Borodzik	University of Warsaw
Olguta	Buse	Indiana University--Purdue University
Olguta	Buse	Indiana University--Purdue University
Carmen	Caprau	California State University, Fresno
Andre	Carneiro	Columbia University
Radu	Cebanu	University of Quebec
Sinem	Celik Onaran	Mathematisches Forschungsinstitut Oberwolfach
Eitan	Chatav	Stony Brook University
Qingtao	Chen	Univeristy of Southern California
David	Clark	Randolph-Macon College
Tim	Cochran	Rice University
Moshe	Cohen	Louisiana State University
Ben	Cooper	University of California, San Diego
Andrew	Cotton-Clay	University of California, Berkeley
Oliver	Dasbach	Louisiana State University
Christopher	Davis	Davis Advisors
Elizabeth	Denne	Smith College
Margaret	Doig	Princeton University
Sean	Droms	University of Virginia
Tolga	Etgu	Koc University
Lyla	Fadali	University of California, San Diego
Bridget	Franklin	Rice University
Michael	Freedman	Microsoft
Agnès	Gadbled	Université de Neuchatel - Institut de Mathématiques
David	Gay	University of Cape Town
Whitney	George	University of Georgia
Allison	Gilmore	Columbia University
Chad	Giusti	University of Oregon
Matthew	Graham	Brandeis University
Joshua	Greene	Columbia University
Eli	Grigsby	Boston College
Shelly	Harvey	Rice University
Kristen	Hendricks	Columbia University
Michael	Henry	University of Texas
Benjamin	Himpel	Aarhus University
Chung-I	Ho	School of math
Matthew	Hogancamp	University of Virginia
Jennifer	Hom	University of Pennsylvania
Peter	Horn	Columbia University
Umberto	Hryniewicz	Federal University of Rio de Janeiro
Burglind	Jöricke	Institut des Hautes Études Scientifiques
Andras	Juhasz	University of Cambridge

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firstname	lastname	institutionname
Aaron	Kaestner	University of Illinois
Tamas	Kalman	University of Tokyo
Amey	Kaloti	Georgia Institute of Technology
Christian	Kassel	Institut de Recherche Mathématique Avancée, Université de
Louis	Kauffman	University of Illinois
Keiko	Kawamuro	University of Iowa
Will	Kazez	University of Georgia
Mikhail	Khovanov	Columbia University
Hee Jung	Kim	Max-Planck Institute for Mathematics
Tatyana	Kobylyatskaya	Harvard University
Robin	Koytcheff	Department of Mathematics, Stanford University
Daniel	Krasner	University of California
Peter	Kronheimer	Harvard University
Aaron	Lauda	Columbia University
Yi-Jen	Lee	Purdue University
Constance	Leidy	Wesleyan University
Adam	Levine	Columbia University
Sam	Lewallen	Princeton University
Joan	Licata	Stanford University
Tye	Lidman	University of California
Yuhan	Lim	University of Adelaide
Robert	Lipshitz	Columbia University
Charles	Livingston	Indiana University
Andrew	Lobb	State University of New York (SUNY)
Adam	Lowrance	University of Iowa Department of Mathematics
Ciprian	Manolescu	University of California, Los Angeles
Thomas	Mark	University of Virginia
Patrick	Massot	Université de Paris XI (Paris-Sud)
Gordana	Matic	University of Georgia
Hiroshi	Matsuda	Hiroshima University
Ben	McCarty	Louisiana State University
Klaus	Mohnke	Humboldt-Universität
Tomasz	Mrowka	Massachusetts Institute of Technology
Thomas	Murphy	National University of Ireland, University College Cork
Max	Murphy	Stanford University
Lenhard	Ng	Duke University
Yi	Ni	California Institute of Technology
Philip	Ording	City University of New York (CUNY)
Peter	Ozsváth	Columbia University
Tim	Perutz	University of Texas
Thomas	Peters	Columbia University
Ina	Petkova	Columbia University
Olga	Plamenevskaya	State University of New York (SUNY)
Candice	Price	University of Iowa
Jozef	Przytycki	George Washington University
Krzysztof	Putyra	Columbia University
You	Qi	Columbia University
Bela	Racz	Princeton University
Jacob	Rasmussen	Cambridge University

Research Workshop: Homology Theories of Knots and Links

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firstname	lastname	institutionname
Danielle	Rice	Portland State University
Rachel	Roberts	Washington University in St. Louis
Lawrence	Roberts	University of Alabama
David	Rose	Duke University
Lev	Rozansky	University of North Carolina
Daniel	Ruberman	Brandeis University
Heather	Russell	Louisiana State University
Bijan	Sahamie	Universität zu Köln
Sheila	Sandon	Université de Nantes
Sucharit	Sarkar	Columbia University
Radmila	Sazdanovic	Serbian Academy of Sciences and Arts (SANU)
Martin	Scharlemann	University of California
Akram	Sheikhalishahi	Sharif University of Technology
Alexander	Shumakovitch	George Washington University
Steven	Sivek	Massachusetts Institute of Technology
András	Stipsicz	Hungarian Academy of Sciences
Ethan	Street	Harvard University
Catharina	Stroppel	Universität Bonn
Zoltan	Szabo	Princeton University
Peter	Teichner	University of California, Berkeley
Dylan	Thurston	Barnard College
Bulent	Tosun	Georgia Insitute of Technology
Eamonn	Tweedy	University of California
Cornelia	Van Cott	University of San Francisco
Jeremy	Van Horn-Morris	American Institute of Mathematics (AIM)
Anne	Vaugon	Université de Nantes
Pedro	Vaz	Technical University of Lisbon
David	Vela-Vick	Columbia University
Ramon	Vera	University of Durham
Vera	Vertesi	MSRI
Oleg	Viro	State University of New York (SUNY)
Kevin	Walker	Microsoft Station Q
Liam	Watson	University of California
Ben	Webster	Massachusetts Institute of Technology
Luoying	weng	SUNY
Simon	Willerton	University of Sheffield
Michael	Williams	University of California
Hao	Wu	George Washington University
Zhongtao	Wu	Princeton University
Rumen	Zarev	Columbia University
Raphael	Zentner	Westfälische Wilhelms-Universität Münster

Research Workshop: Homology Theories of Knots and Links

March 15 - 19, 2010 at MSRI, Berkeley, CA

Officially Registered Participant Information

Participants		**138**

Gender		**138**
Male	70.29%	97
Female	25.36%	35
Declined to state	4.35%	6

Ethnicity*		**142**
White	76.76%	109
Asian	11.27%	16
Hispanic	2.82%	4
Pacific Islander	0.00%	0
Black	1.41%	2
Native American	0.00%	0
Declined to state	7.75%	11

* ethnicity specifications are not exclusive

Report on the "Hot Topic" Workshop "Black Holes in Relativity"

The workshop focused on the emergent area of mathematical research dedicated to the study of black holes and related dynamical phenomena arising in General Relativity. The subject has undergone an incredible transformation in the last 5 years accompanied by the a new evolving understanding of the mathematical properties of black holes. Nothing is more emblematic of this revolutionary progress than the recent work of Demetrios Christodoulou on formation of black holes. This result was chosen as a central theme of the workshop.

The mathematical study of the dynamics of the Einstein equations forms a central part of both partial differential equations and geometry, and is intimately related to our current physical understanding of gravitational collapse. The celebrated singularity theorems of Penrose, proven in the 1960s, showed that geodesic incompleteness is inevitable provided that initial data contain what is known as a closed trapped surface. Trapped surfaces are also related to the presence of black holes. A breakthrough into the understanding of trapped surface formation has recently been achieved by Christodoulou in his 600 page monograph: "The formation of black holes in General Relativity", Publications of the EMS, January 2009, where it is shown that trapped surfaces form in evolution for the Einstein vacuum equations from completely dispersed initial configurations, a phenomenon caused purely by the focussing of gravitational waves. The proof brings together ideas from geometric analysis and non-linear hyperbolic equations and at the same time introduces new techniques adapted to large data problems. The methods will undoubtedly have many future applications in both general relativity and other equations of mathematical physics. In particular, the work provides the first global "large data" result in general relativity (without symmetry assumptions) and opens the possibility for many new developments on dynamical problems relating to black holes.

The workshop brought together experts in General Relativity, Hyperbolic Equations and Geometric Analysis. It was particularly successful in attracting a large number of graduate students and postdocs (Baskin, Bieri, Chen, Ghanem, Holzegel, Huang, Jang, Luk, Nguyen, Oh, Rubinstein, Smulevici, Speck, Tohaneanu, Yang) who had an opportunity to be exposed to the cutting edge research in these areas and to interact with the senior participants (Bartnik, Christodoulou, Dafermos, Eskin, Friedlander, Galloway, Isenberg, Kapitanski, Lindblad, LeFloch, Mazzeo, Rendall, Rodnianski, Sideris, Schoen, Vasy, Wang, Weinstein). This type of mixture of very junior and very senior participants is unique for meetings in these subjects. A typical workshop is either a high intensity scientific meeting with a large number of talks focused narrowly on the very latest advances and thus allowing very little room for junior participants, or has a summer school format concentrating on the educational component but providing very little interaction between junior and (very few) senior participants. In the current workshop the interaction proved to be extremely useful and beneficial for both sides. The junior participants in particular have been unanimous in their satisfaction with the chosen topic and the format of the workshop.

The 5-day workshop begun on Monday, September 14 and ended on Friday, September 18. Its format, with the exception of Wednesday, was an hour lecture in the morning, followed by lunch, and two one hour lectures in the afternoon. Such scheduling left an ample time for interaction between the participants and additional discussions, an arrangement highly appreciated by all the partcipants.

The scientific part of the workshop was focused on the breakthrough work of Demetrios Christodoulou on formation of black holes. A major coup was achieved in securing an agreement from Christodoulou to come to the workshop and explain the content of his work. Christodoulou gave 5 highly detailed and comprehensive lectures explaining the philosophy, technical constructions and conclusions of his result. As his work is a revolutionary tour de force both relying on and altering the understanding of the evolution problem in General Relativity, it was further aided by two introductory lectures addressing that precise subject.

The workshop started on Monday with the introductory remarks by the MSRI Director Robert Bryant and the first introductory lecture by Mihalis Dafermos on the evolution problem in General Relativity, followed by the first lecture of Christodoulou. The day ended with the second introductory lecture by Alan Rendall on the characteristic initial value problem in General Relativity. The framework of characteristic value problem is a crucial element of the Christodoulou's result.

The second day of the conference began with the second lecture by Christodoulou, followed by a lecture by Greg Galloway on topology of the marginally trapped surfaces in 2+1 and higher dimensional gravity. The day ended with an excellent lecture by Jim Isenberg in which he surveyed a very active field of the constraint equations in General Relativity. Both lectures provided an invaluable complementary point of view to the lectures of Christodoulou concerned with the evolution problem in General Relativity.

The third day continued with another (two 1 hour lectures) installment from the series of lectures by Christodoulou, followed by a talk by Spyros Alexakis on the recent progress on the black hole rigidity problem. This is a fascinating long standing question concerning uniqueness of the Kerr family of black hole solutions in the class of stationary asymptotically flat spacetimes. The initial breakthrough was achieved in the 70's in the work of Carter, Israel, Robinson and Hawking culminating in the rigidity statement for the analytic spacetimes. Alexakis explained recent results aimed at removing the analyticity assumption. The last talk of the day was by Robert Bartnik on the topic of the Hamiltonian formulation of General Relativity.

On Thursday, Christodoulou delivered the last of his lectures. The rest of the day focused on the subjects related to another outstanding open problem in General Relativity – stability of black holes. While the work of Christodoulou established the sufficient conditions under which a trapped surface, and thus potentially a black hole, forms in evolution, the problem of nonlinear stability of basic black hole solutions – Schwarzschild and Kerr families – has been open since their respective discoveries in 1916 and 1963. The last 5 years have seen a significant progress towards the solution of the problem as punctuated both by the results on the linear stability and development of the methods relevant to the nonlinear problem. Mihalis Dafermos gave a sweeping overview of the problem and the recent breakthrough results in the subject. His lecture was followed by 4 shorter (half-hour) talks of the junior participants on their results. Pieter Blue and Mihai Tohaneanu spoke about the decay and Strichartz estimates for the wave equation in Schwarzshild and Kerr spacetimes, Gustav Holzegel explained his new results on the boundedness for solutions of the Klein-Gordon equation in Kerr-anti de Sitter spacetime, and Dean Baskin gave a talk on the parametrix construction for the Klein-Gordon equation in an asymptotically de Sitter spacetime.

The last day of the workshop started with the lecture by Igor Rodnianski who described the almost immediate impact of the discussed work of Christodoulou given in the extension and reinterpretation of the new short-pulse method. The last two talks were by Maciej Zworski and Mu-Tao Wang. Zworski's lecture addressed the subject of quasi-normal modes of solutions of the wave equation on stationary black hole spacetimes and their importance to numerical and observational relativity and high energy physics. Wang's lecture focused on another important subject of General Relativity – quasi-local mass and described recent important results in the area.

A special lunchtime event took place on Thursday. The discussion was moderated by Christodoulou and was designed mostly for the junior participants. The discussion revolved around open problems in Hyperbolic Equations and General Relativity. Among several discussed subjects were nonlinear electrodynamics and uniqueness problems in General Relativity.

Participants reported a high level of satisfaction with the scientific content and the format of the workshop. According to the informal polling the only weak point of the workshop was a catered lunch which provided neither quality or healthy options nor the diversity of choices or reasonable prices. Everyone was thrilled about the location of the workshop and the MSRI building. Participants were universal in their praise for the quality of the auditorium, audio and video equipment (it has been reported that these have been enjoyed by the participants who wanted to refresh their memories upon the return to their home institutions as well as by people who did not attend the workshop). Participants particularly noted generous financial support and help from the MSRI staff.

The workshop was organized by Mihalis Dafermos (University of Cambridge) and Igor Rodnianski (Princeton University) with the invaluable and highly professional help from the MSRI staff.

Hot Topics: Black Holes in Relativity

Invited Speakers

Alexakis, Spyridon	Eidgenössische TH Zürich-Zentrum
Bartnik, Robert	Monash University
Baskin, Dean	Stanford University
Blue, Pieter	University of Edinburgh
Christodoulou, Demetrios	Princeton University
Dafermos, Mihalis	University of Cambridge
Galloway, Greg	University of Miami
Holzegel, Gustav H	Princeton University
Isenberg, James Allen	University of Oregon
Rendall, Alan David	Max Planck Institute für
Rodnianski, Igor	Princeton University
Tohaneanu, Mihai Horia	Purdue University
Wang, Mu-Tao	Columbia University
Zworski, Maciej	University of California, Berkeley

MSRI Mathematical Sciences Research Institute

Hot Topics: Black Holes in Relativity

September 14 to September 18, 2009

Monday September 14, 2009		
09:40AM - 10:00AM	Welcoming, Robert Bryant, MSRI Director	
10:00AM - 11:00AM	Mihalis Dafermos	An introduction to the problem of evolution in general relativity
11:00AM - 11:30AM	Coffee, tea in the atrium	
11:30AM - 12:30PM	Demetrios Christodoulou	Formation of black holes
12:30PM - 02:00PM	Lunch	
02:00PM - 03:00PM	Alan Rendall	The characteristic initial value problem in General Relativity
03:00PM - 03:30PM	Coffee, tea in the atrium	
Tuesday September 15, 2009		
10:00AM - 11:00AM	Demetrios Christodoulou	Formation of black holes
11:00AM - 11:30AM	Coffee, tea in the atrium	
11:30AM - 12:30PM	Greg Galloway	Aspects of marginally trapped surfaces in 2+1 and higher dimensional gravity
12:30PM - 02:00PM	Lunch	
02:00PM - 03:00PM	James Isenberg	Constraint equations of General Relativity
03:00PM - 03:30PM	Coffee, tea in the atrium	
Wednesday September 16, 2009		
10:00AM - 11:00AM	Demetrios Christodoulou	Formation of black holes
11:00AM - 11:30AM	Coffee, tea in tha atrium	
11:30AM - 12:30PM	Spyridon Alexakis	On black holes uniqueness
12:30PM - 02:00PM	Lunch	
02:00PM - 03:00PM	Robert Bartnik	ADM revisited
03:00PM - 04:00PM	Coffee, tea in the atrium	
Thursday September 17, 2009		
10:00AM - 11:00AM	Demetrios Christodoulou	Formation of black holes
11:00AM - 11:30AM	Coffee, tea in the atrium	
11:30AM - 12:30PM	Mihalis Dafermos	The black hole stability problem
12:30PM - 02:00PM	Lunch	
02:00PM - 02:30PM	Pieter Blue	Hidden symmetries and decay for the wave equation in Schwarzschild and Kerr spacetimes
02:30PM - 03:00PM	Gustav Holzegel	The massive wave equation on Kerr-AdS spacetimes
03:00PM - 03:30PM	Coffee, tea in the atrium	
03:30PM - 04:00PM	Mihai Tohaneanu	Strichartz estimates on Schwarzschild and Kerr spacetimes
04:00PM - 04:30PM	Dean Baskin	The Klein-Gordon equation on asymptotically de Sitter spaces
05:00PM - 07:00PM	Reception in the atrium	
Friday September 18, 2009		
10:00AM - 11:00AM	Igor Rodnianski	On the short pulse method and its applications
11:00AM - 11:30AM	Coffee, tea in the atrium	
11:30AM - 12:30PM	Maciej Zworski	Quasinormal modes (resonances) for black holes
12:30PM - 02:00PM	Lunch and beyond discussion of open problems	
02:00PM - 03:00PM	Mu-Tao Wang	Quasi-local mass
03:00PM - 03:30PM	Coffee, tea in the atrium	

Currently Available Videos

- **Mihalis Dafermos** , An introduction to the problem of evolution in general relativity *September 14,2009, 10:00 AM to 11:00 AM*
- **Demetrios Christodoulou** , Formation of black holes *September 14,2009, 11:30 AM to 12:30 PM*
- **Alan Rendall** , The characteristic initial value problem in General Relativity *September 14,2009, 02:00 PM to 03:00 PM*
- **Demetrios Christodoulou** , Formation of black holes *September 15,2009, 10:00 AM to 11:00 AM*
- **Greg Galloway** , Aspects of marginally trapped surfaces in 2+1 and higher dimensional gravity *September 15,2009, 11:30 AM to 12:30 PM*
- **James Isenberg** , Constraint equations of General Relativity *September 15,2009, 02:00 PM to 03:00 PM*
- **Demetrios Christodoulou** , Formation of black holes *September 16,2009, 10:00 AM to 11:00 AM*
- **Spyridon Alexakis** , On black holes uniqueness *September 16,2009, 11:30 AM to 12:30 PM*
- **Demetrios Christodoulou** , Formation of black holes *September 16,2009, 02:00 PM to 03:00 PM*
- **Robert Bartnik** , ADM revisited *September 16,2009, 03:00 PM to 04:00 PM*
- **Demetrios Christodoulou** , Formation of black holes *September 17,2009, 10:00 AM to 11:00 AM*
- **Mihalis Dafermos** , The black hole stability problem *September 17,2009, 11:30 AM to 12:30 PM*
- **Pieter Blue** , Hidden symmetries and decay for the wave equation in Schwarzschild and Kerr spacetimes *September 17,2009, 02:00 PM to 03:00 PM*
- **Gustav Holzegel** , The massive wave equation on Kerr-AdS spacetimes *September 17,2009, 02:30 PM to 03:00 PM*
- **Mihai Tohaneanu** , The Klein-Gordon equation on asymptotically de Sitter spaces *September 17,2009, 03:30 PM to 04:00 PM*
- **Dean Baskin** , The Klein-Gordon equation on asymptotically de Sitter spaces *September 17,2009, 04:00 PM to 04:30 PM*
- **Igor Rodnianski** , On the short pulse method and its applications *September 18,2009, 10:00 AM to 11:00 AM*
- **Maciej Zworski** , Quasinormal modes (resonances) for black holes *September 18,2009, 11:30 AM to 12:30 PM*
- **Mu-Tao Wang** , Quasi-local mass *September 18,2009, 02:00 PM to 03:00 PM*

You can find videos of other workshops and events on our VMath - Streaming Video page.

Participant List

MSRI Workshop:

Hot Topics: Black Holes in Relativity

September 14-18, 2009

at Mathematical Sciences Research Institute, Berkeley California

Name	Institution
Alexakis, Spyridon	Eidgenössische TH Zürich-Zentrum
Azimian, Amin	Islamic Azad University,South Tehran
Bartnik, Robert	
Baskin, Dean	Stanford University
Beheshti, Shabnam	Rutgers University
Bieri, Lydia Rosina	Harvard University
Blue, Pieter	University of Edinburgh
Chen, PoNing	Mathematics Department
Chen, Szu-yu Sophie	Princeton University
Christodoulou, Demetrios	Princeton University
Chrusciel, Piotr T.	University of Oxford
Dafermos, Mihalis	University of Cambridge
dain, Sergio Alejandro	National University of Córdoba
De Oliveira, Wellington	Federal University of Paraíba
Eskin, Gregory	University of California
Foualdgar, Kaveh	Stanford University
Friedlander, Susan	University of Southern California
Galloway, Greg	University of Miami
Gelbord, Todd R.	Montana State University
Ghanem, Sari	University of Wisconsin
Hadzic, Mahir	Brown University
Heile, Frank	
Holzegel, Gustav H	Princeton University
Huang, Lan-Hsuan	Mathematics Department, Stanford University
Isenberg, James Allen	University of Oregon
Jang, Juhi	Courant Institute of Mathematical Sciences
Kapitanski, Lev	
kartsaklis, anastasios christos	Univ. Of Athens,Dert. of Mathematics
Keel, Markus	University of Minnesota Twin Cities
Kharel, Savan	University of Tennessee
Kong, De-Xing	Zhejiang University
Krieger, Joachim	Harvard University
Laul, Parul	University of Toronto
LeFloch, Philippe	Centre National de la Recherche Scientifique (CNRS)
Lindblad, Hans	University of California, San Diego
Luk, Jonathan Winghong	Princeton University
Mazzeo, Rafe	Stanford University
Metcalfe, Jason L.	University of North Carolina
Metzger, Jan	Stanford University
mishra, pawan kumar	Motilal Nehru National Institute of Technology
Nakamura, Makoto	Tohoku University
Nguyen, Xuan Hien	Kansas State University
Oh, Sung-Jin	Princeton University
Oliver, Jesus Rafael	University of California
Pollack, Daniel	University of Washington
Ponge, Raphael S.	University of Tokyo
Psarelli, Maria	BCC-CUNY
Rendall, Alan David	Max Planck Institute für Gravitationsphysik, Albert-Einstein-Institut
Rodnianski, Igor	Princeton University
Roth, Ilan	Space Sciences, UC Berkeley
Rubinstein, Yanir	Johns Hopkins University
Schoen, Richard M.	Stanford University
Shao, Arick	Princeton University

Shao, Shuanglin	Institute for Advanced Study
Shatah, Jalal	New York University, Courant Institute
Shiromizu, Tetsuya	Kyoto University
Sideris, Thomas	University of California
Smulevici, Jacques	DAMTP Centre for Mathematical Sciences
Speck, Jared	Princeton University
Sterbenz, Jacob	UCSD
Tahvildar-Zadeh, A. Shadi	Rutgers University
Tanabe, Kentaro	Yukawa Institute for Theoretical Physics
Tod, Kenneth Paul	University of Oxford
Tod, Paul	University of Oxford
Tohaneanu, Mihai Horia	Purdue University
Tutberidze, Mikheil	Tbilisi State University
Vasy, András	Stanford University
Visan, Monica	University of Chicago
Wang, Mu-Tao	Columbia University
Wang, Shouhong	Indiana University
Warchall, Henry A.	National Science Foundation
Weinstein, Gilbert	University of Alabama, Department of Mathematics
Whitman, Phillip	Princeton University
Wildman, Chad Thornton	University of California, San Diego
Williams, Catherine Mary	Stanford University
Wong, Percy	Princeton University
Wunsch, Jared	Northwestern University
Yamada, Sumio	Tohoku University
Yang, Shiwu	Princeton University
Yu, Peng Peng	University of Wisconsin
Zworski, Maciej	UCB - University of California, Berkeley

Hot Topics: Black Holes in Relativity
Held: September 14-18, 2009
The Mathematical Sciences Research Institute

Officially Registered Participant Information
83 participants

Gender (n = 80participants)		
Male	85.00%	68
Female	13.75%	11
Declined to state	1.25%	1

Ethnicity (n =72 participants)		
White	58.33%	42
Asian	30.56%	22
Hispanic	1.39%	1
Pacific Islander	0.00%	0
Black	0.00%	0
Native American	0.00%	0
Declined to state	9.72%	7

MATHEMATICAL SCIENCES RESEARCH INSTITUTE
Critical Issues in Mathematics Education Workshop
Reasoning and Sense-Making in the Mathematics Curriculum
July, 2010

The seventh Critical Issues in Mathematics Education workshop took place at MSRI June 7–9, 2010. *Reasoning and sense-making*, the theme of the workshop, was discussed with respect to three different areas: Standards for mathematics, different national systems in four very different countries (Singapore, Australia, India, and the U.S.), and classroom instruction (assessment, textbooks, technology). The audience for the workshop included mathematicians, mathematics educators, classroom teachers, and education researchers.

The Common Core State Standards for mathematics were released five days before the workshop began. The lead writers William McCallum and Jason Zimba gave an overview of the Standards and upcoming concerns for assessment.

A talk by educational researcher William Schmidt put the structure of the Standards in context, describing how topics in K–12 curricula from different countries were sequenced across the grades and displaying the sequence for the Common Core State Standards.

Teachers from the Raffles Girls' School in Singapore and their department head gave an overview of their educational system and described aspects of secondary mathematics at their school. Sridhar Rajagopalan, managing director of Educational Initiatives, which has the aim of improving India's educational system, described the work of his organization. Helen Chick, a mathematics education researcher in Australia, described Australian standards. Elizabeth Burns, an Australian teacher, gave some classroom context.

Other talks at the workshop focused on how reasoning and sense-making could be supported at the classroom level by textbooks, assessment, and technology. Speakers included Henry Kepner (immediate past president of the National Council of Teachers of Mathematics) and Linda Gojak (a past president of the National Council of State Supervisors of Mathematics), as well as mathematicians involved with mathematics education in a variety of ways.

As always with MSRI Critical Issues workshops, participants (including speakers) had opportunities for discussion after the talks and during meals and coffee breaks.

Over 140 people participated in the workshop, and the workshop will benefit even more people than the participants. We have created a web site to serve as the home of the workshop series. The URL is http://www.msri.org/specials/cim. Descriptions of all seven workshops are available from this web page. This includes slides and video from presentations, schedules, and lists of participants. The workshop-specific web pages also contain links to publications resulting from the workshops. These include:

Assessing Mathematical Proficiency
edited by Alan H. Schoenfeld
Cambridge University Press, Cambridge, 2007, xix + 391p.
ISBN-13: 978-0-521-87492-2 (hardback), 978-0-521-69766-8 (paperback)

as well as the booklets

Using Math to Teach Math
(http://www.msri.org/calendar/attachments/workshops/318/MSRI_MKT_booklet_july28.pdf)

and

Teaching Teachers Mathematics: Research, Ideas, Projects, Evaluation
(https://secure.msri.org/calendar/attachments/workshops/430/TTM.pdf/)

We are in the process of producing booklets on *Teaching and Learning Algebra*, *Teaching Undergraduates Mathematics*, and *Reasoning and Sense-Making in the Mathematics Curriculum*.

MPDI Summer Institute 2009:

Final Report

H. Wu, October 11, 2009

This is a report on the three weeks of activities from July 6 to July 24 in the 2009 Mathematics Professional Development Institute held at MSRI. It has two parts: the first part is a general summary and the second part consists of the verbatim transcriptions of the anonymous evaluations by the 24 participants.

Part I: General Summary

This is a professional development institute devoted to **pre-algebra**. While it directly addresses middle school mathematics and would be helpful to any middle school teacher, it is not designed to stand alone. It is meant to be the first part of a two-institute sequence, where the second part will be devoted to roughly **Algebra I**. If funded, the 2010 institute will address algebra itself.

We accepted 26 teachers, although we only had funding for 24. We expected some drop-outs, and two did just that: one dropped out before the institute began, and the other did after one week of instruction. We tried to be careful in the selection of the participants, but due to miscommunication and misunderstanding, we did make one mistake. The remaining 23 were, however, as good a group as could be expected. There was a core of about ten teachers among the 23 that were truly outstanding in terms of dedication and content knowledge, and they pretty much set the tone for the institute.

Two teachers attended every day of the institute without a stipend, and a few visitors came for a period of a few hours throughout the three weeks.

The syllabus of the fifteen-day institute is as follows:

fractions ($4\frac{1}{2}$ days)

rational numbers ($2\frac{1}{2}$ days)

experimental geometry (2 days)

geometry of transformations (6 days)

School algebra stands on two pillars: rational numbers (including fractions) and the geometry of similar triangles. Unfortunately, these topics are either not taught to middle school teachers (in the case of similar triangle) or taught badly (in the case of rational numbers). For this reason, the 2009 institute tried to remedy the existing situation by providing a firm *mathematical* foundation for both.

By now, the approach to fractions via the number line seems to be somewhat familiar to most of the teachers. However, a reasonable presentation of negative numbers (second topic) was foreign to almost all of them, and the eight days on geometry taught from the point of view of transformations were completely new to them all. They became enthusiastic after an initial period of shock, and it can be seen from the evaluations of Part II that almost all of them embraced this way of teaching geometry at the end. The two days of experimental geometry seemed to be critical in turning them around; the fact that a great deal of school mathematics is grounded on experiments was news to them.

A set of lecture notes totaling 347 pages was given out to all participants. The lectures (totaling about four hours each day) were based entirely on the notes. Because the content of this institute is unlike that of other professional development institutes, the participants could not have followed the lectures without these notes.

The evaluations testify to the fact that most participants found the institute to be helpful. The positive comments about what the teachers learned in the small group sessions validate the commitment of the institute to getting very strong small group leaders. A few teachers complained that the content was overwhelming, the pace was too fast, the homework assignments were too demanding, etc. Given the design of the institute, perhaps it is impossible to adequately deal with these complaints. One suggestion was very helpful, however, to the effect that the institute should devote the beginning of each day to explaining an outstanding homework problem of the night before. The participants also made very good suggestions about how the Saturday sessions should be structured: let the teachers talk about their teaching experiences, with mathematical comments added when necessary. The first such session, held on September 19, followed this suggestion exactly, and the teachers' comments seemed to vindicate the approach.

The design of the institute is to teach a few teachers very well, and hope that some of them will go back and help spread the message of the importance of content knowledge. The 2009 institute seems to be the first time that this idea bears fruit. One of the participants, Jacob Disston, a middle school teacher from Berkeley USD, wrote the following on October 7:

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-------- Original Message --------
Subject:  next summer
Date:  Wed, 07 Oct 2009 20:43:29 -0700
From:  Jacob Disston <Jacob_Disston@berkeley.k12.ca.us>
To:  Wu <wu@math.berkeley.edu>

hi wu:  i know this is early, but do you have any idea what the dates
will be for next summer's institute?  i'm really trying to talk it up
with teachers at my school.

thanks for any information about possible dates,
jake
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He is clearly trying to get more teachers from his school to come to the 2010 institute.

Right after the conclusion of the institute, Wu received the following email from Drew Braun, the district math supervisor of two of the participants (Christina Coombs and Kelly Leguizamon, from Eugene, Oregon) in the 2009 institute:

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-------- Original Message --------
Subject:  Follow-up
Date:  Mon, 31 Aug 2009 16:28:39 -0700
From:  Braun, Drew <dbraun@bethel.k12.or.us>
To:  <wu@math.berkeley.edu>

Wu,

I met last Thursday with Kelly and Christina.  They are excited about
implementing what they learned at the Institute in their classrooms and
sharing with other teachers.  They are also looking for to the 5 follow-up
sessions and if possible participating in the Institute again next summer.

We also met with our two math coaches (one participated in the U of O
Mathematicians Workshops and attended your session).  We discussed how
we might take what Kelly and Christina learned this summer and impact
mathematics instruction here in Bethel.  The consensus was to get other
teachers on board and provide ongoing professional development.

I am writing to ask if it is possible for you to provide the initial professional
development, here in Eugene, on October 9th or October 19th (6-8 hours
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in length)? The audience would be elementary, middle school and high school math teachers including those that teach special education. The goal would be for teachers to have a better understanding of why we need to change our approach to mathematics and the need for consistency in the approach as student move from whole numbers to rational numbers to algebra.

We would then follow-up by providing monthly workshops on topics that are grade level appropriate with Kelly, Christina, and our math coaches.

I realize this is short notice for your busy schedule. If it is not possible any other alternatives or suggestions would be greatly appreciated.

Thank you again for the wonderful experience this summer for Kelly and Christina.

Drew

Drew Braun, Ph.D./

Director of Instruction/

(541) 689-3280/

As a result, Wu will be going up to Oregon on October 17, 2009, to give a presentation to teachers about why a better content knowledge on the part of teachers would lead to greater learning opportunities for students.

Both developments are encouraging.

Part II: Teachers' Anonymous Evaluations

On the last day of the 2009 institute (July 24), the participants were asked to spend an hour to write, anonymously, their thoughts on five questions:

1. What were the benefits of attending this type of institute?
2. What improvements do you suggest? Please be specific.
3. What would you like to see happen during the Saturday sessions? How would you like them organized? Please be specific. Consider format, topics, etc.
4. What are you going to implement/change in your classroom because of what have you learned in this institute?
5. Are you planning to work with colleagues in your school who have not attended the institute? What are your specific plans to implement this?
6. Do you have to report to an administrator/district/school personnel employee with a summary of what you did during the institute? If you, whom will you report to and how?
7. Additional Comments

The following are the verbatim transcriptions of their comments. Note that a few teachers signed their names to the questionnaire.

Evaluation #1

1. What were the benefits of attending this type of institute?

This has been an extraordinary experience, with a lecture followed by small groups was crucially important. Learning was reinforced and the collaborative spirit of the group was very encouraging. I am much more cognizant of my mathematical shortcomings, but also fairly confident that with time, patience and a lot of hard work on my part, I can expand my knowledge and convey that to my students successfully. Other benefits of the institute are just related to broadening my circle of "math friends" and having people to work with, share ideas, and continue to pursue math learning opportunities. The good and bad of the program is that so much material is crammed into 3 weeks and I can not predict how that will impact my retention.

2. What improvements do you suggest? Please be specific.

I suggest finding more group leaders who are mathematicians or grad students in mathematics. That is not to say that we can not all learn from one another. The fertile exchange of ideas, techniques etc, in the small groups attest to that. At the same time, I believe there was a significant difference in the value/learning that took place in the afternoon when Sunil was at the helm. He was able to give guide us and challenge us in ways that Winnie and Stephanie could not. (See more on back page)

3. What would you like to see happen during the Saturday sessions? How would you like them organized? Please be specific. Consider format, topics, etc.

I would like to ask folks to discuss specifically how they've implemented what they learned and what did and didn't work. Perhaps specific topics could be predetermined for particular sessions. I would also like the opportunity to learn more and reinforce the concepts that are more complex.

4. What are you going to implement/change in your classroom because of what have you learned in this institute?

I foresee using significant parts of Ch. 1 and 2 and I plan to use the number line as a core tool. I plan to use the exercises in Ch. 4 (with transparencies) and think they will be very powerful, especially for students who are very intimidated by mathematics. They will also be fun, and can go a long way towards breaking down barriers.

On a more personal level, I will challenge myself to be extremely thorough and explicit and be clear about definitions. I can foresee more prep time to achieve these goals, but I anticipate that the pay-off will be significant.

5. Are you planning to work with colleagues in your school who have not attended the institute? What are your specific plans to implement this?

Yes. My main colleague is very interested in the things we've been learning here and he is anxious to meet with me. We have discussed our desire to continue to modify and improve curriculum and I hope to focus on the key topics from this institute. I will share all the materials and do my best to convey what I've learned. The administration is open to innovation as well, so there is enormous potential for growth at my school.

6. Do you have to report to an administrator/district/school personnel employee with a summary of what you did during the institute? If you, whom will you report to and how?

No

7. Additional Comments (use back if necessary):

I would like to comment on the lecture notes. I think it would have been valuable to obtain the notes in advance of the institute (even just a few weeks before) to get a chance to preview the material. Regarding the content of the notes: many times a theorem or concept is referred to, and I want to refresh my memory about it - It would be helpful to have a page reference included to be able to flip back to something previously presented. It would also be great to have an index at the end or, several pages at the end with proofs collected together by topic.

Evaluation #2

1. What were the benefits of attending this type of institute?

My understanding of the underlying and unifying ideas of math is greatly improved. There is still much to improve and solidify so work will continue! I now understand what is key and will focus my time and energy there with my students.

My expectations of my students will be higher in two ways:
(1) I will be teaching better/more, so the expectations can be higher
(2) Their clarity and completeness in responses, written or oral is expected now. We learn the why and how, so good explanations follows.

This helped me even more strongly identify with children who are at their "frustration level", (independent, instructional, frustration) and reinforce why teaching is multi-model and multidimensional while at the same time follows a linear, clear path. Having community of teacher-learners with me gave me support and a common language to help me connection and clarify, especially those whose grade level (and their experience) was close to mine.
Having Jake and Claudia was so important and really helped my understanding.

2. What improvements do you suggest? Please be specific.

Afternoon Sessions - try self-selected level groups some of the time?
Some don't ask for help when lost as they don't want to slow the groups down. Although it is great to hear those who are clear(er) explain it! but when whole conversation moves too quickly, all is lost.
Last 3 afternoons: 1/2hs/day to discuss how to teach at a particular grade level? This really clarifies the sequencing that sometimes we lose track of when we're "in it" learning.
Fewer/no non-examples until we're clearer on what is.
Less talk and what us people "usually do" or "what is bad" - this gets mixed into what is Wu and good. I want to remember all that comes from Wu as being correct, an example, or a good non-example. Once we know what is correct, we can compare that with/what is usually done in schools/tests and that comparison done then is helpful and clear. Really I assume all my teaching isn't great (hence I'm here!) and I know the texts are horrid (Lang. Arts too!) so one can just have "g" stand for that discussion and after a few days, we can simply say, We know g, thus we'll now look at .... :-)

3. What would you like to see happen during the Saturday sessions? How would you like them organized? Please be specific. Consider format, topics, etc.

Scope and sequence for year w/spacing
What has helped teachers make ideas clear to students
How t's reach and support lessons who struggle and/or have holes (-method: -school arrangements -etc!)
Ideas for introducing and/or weaving in "geometric" parts of year <u>into</u> the usual +,-,$\times$, $\div$ of whole #/fract./dec." beginning
Haven't thought (the above) this through and may not make sense - have to look at seg(?)
(Will look at Kay's sequence for 4/5th to help me)

If we have a group email (yahoogroups) we could share ideas for Sat's as we move through the year diff things come up, some unexpected.

4. What are you going to implement/change in your classroom because of what have you learned in this institute?

Goodness. Where to Start!

Everything tied to the number line throughout the year.
Specific vocabulary-definitions so that not only is math taught correct, but this creates a solid platform for kids to build on, especially those who need to hear things a million times before the "a-ha! So that's what you've being saying!" In self-contained classroom will <u>all</u> levels included (from extremely gifted kids who are in Intervention) this is SO important! They'll have the language, visuals, and concepts line up coherently and correctly.
I always ask my kids, "why?" but now I have given the correct explanation! :-)

5. Are you planning to work with colleagues in your school who have not attended the institute? What are your specific plans to implement this?

This is tricky in elementary where most love lang arts and "do math".
I'm thinking about it as introducing them to a new culture's food. You have then try what's closest to what they know and is most palatable, like the number line. Once they see how it makes things easier, they'll be interested in trying something else, and so on. Over the copier, I'm going to post mini-lessons so while we're standing there, we're thinking.

6. Do you have to report to an administrator/district/school personnel employee with a summary of what you did during the institute? If you, whom will you report to and how?

No.

$\cdots$ but I will give him a Wu paper to read to begin his journey! :-) and start a dialogue!

7. Additional Comments (use back if necessary):

Evaluation #3

1. What were the benefits of attending this type of institute?

- Help me see why students are having trouble learning math
- Give me an idea about how to make my teaching more efficient
-confirm me on the way I was thinking we should teach math

2. What improvements do you suggest? Please be specific.

3. What would you like to see happen during the Saturday sessions? How would you like them organized? Please be specific. Consider format, topics, etc.

I do think we need to talk a lot more about similarity. Only after that go to area length and volume.

4. What are you going to implement/change in your classroom because of what have you learned in this institute?

While I don't teach exactly the way the textbook suggests, I try to teach in the same order the book did. "sequencing" will be a keyword on my way of teaching from now.

5. Are you planning to work with colleagues in your school who have not attended the institute? What are your specific plans to implement this?

- Explain to them the benefits of teaching that way
- Give them a copy of the lecture notes.
- Let them know I'm available to answer all their questions (will do my best).
- In case I need it, ask for a help from Wu - via an email.

6. Do you have to report to an administrator/district/school personnel employee with a summary of what you did during the institute? If you, whom will you report to and how?

No

7. Additional Comments (use back if necessary):

What will you do if you find yourself at the end of the year with a lot of kids failing your class because your way of teaching math is just new for them.

Evaluation #4

1. What were the benefits of attending this type of institute?

So many! Learning how to be more precise and truly knowing what we are teaching. Learning or relearning vocabulary. This institute I really experienced what it feels like to be a student again esp when a student is struggling. I hope to have more compassion for my students who don't understand, then try to build on concepts they do understand. The institute makes me hungry to learn more so I can better serve my students.

2. What improvements do you suggest? Please be specific.

I would have loved to have typed this questionnaire for you. You can tell my writing and spelling are very poor :-). I would have liked to have someone to work more one on one with. Not all of our mentors were very approachable at times.

3. What would you like to see happen during the Saturday sessions? How would you like them organized? Please be specific. Consider format, topics, etc.

I enjoyed how the sessions were set up last year where I was able to bring examples of things that worked for me and concepts that I needed to improve on. I also liked the fact that the Saturday sessions tended to be smaller.

4. What are you going to implement/change in your classroom because of what have you learned in this institute?

Last year after the number sense institute I really worked on sequencing this year I would like to have a stronger base in # sense and reasoning so I can be more clear in my explanations.

5. Are you planning to work with colleagues in your school who have not attended the institute? What are your specific plans to implement this?

Yes! I was bummed that one of my colleagues was not accepted into the institute because it was full. I know she will want to work w/me. I would like to have my colleagues and my principal come to the Saturday sessions. I will be co-teaching for the 1st time next year, as we are planning I will be sharing my "Wu" notes w/them.

6. Do you have to report to an administrator/district/school personnel

employee with a summary of what you did during the institute? If you, whom will you report to and how?

No. My principal encouraged me to come last year. This year it was my call.

7. Additional Comments (use back if necessary):

Wu thank you for everything that you do! I hated math until I was in college, I think part of the reason was that most teachers cannot explain concepts clearly even though we have the best intensions at heart. I would be so grateful if I could prevent the majority of my students from not being able to reason through math. This institute is very chalanging, but it forces you to grow I have really enjoyed them, I hope to take the # sense institute again in the near future. I really liked Stephanie's style of teaching as well, I would take a class from her anytime :-)

Evaluation #5

1. What were the benefits of attending this type of institute?

· This is a wonderful way to begin to think about mathematics in a mathematical way (formally, precisely, carefully, logically). What a privilege to learn under a math professor.
· Getting to know Dr. Wu our excellent mentors (Winnie, Stephanie and Sunil) and all of the teachers.
· The institute, three week session forces (allows) the deep thinking required for root change.
· The geometry topics were perfect for me personally. Having just taught high school geometry last year, I was freshly familiar with the topics, but not ingrained yet w/bad habits was unbelievably perfect!
· Proofs! Proofs! Proofs! What a great opportunity to begin to learn how to do proofs and reason carefully. THANK YOU!

2. What improvements do you suggest? Please be specific.

It would be good if you emailed the questionnaire to us a head of time, even as early as the beginning of the week.

That would give time for us "processors" to think through our responses and even make some specific plans. (We could still take time the last day to write our responses).

3. What would you like to see happen during the Saturday sessions? How would you like them organized? Please be specific. Consider format, topics, etc.

More Wu topics

Format:
· Time to visit.
· Some formal instruction from Wu. (anything from Chapter 3/more in-depth on length-area-volume/anything else he wants to discuss. Algebra would be great too, but might not be what the rest of the group wants).
· Activities or interactions related to instruction
· Time to share ideas/request suggestions from our classroom efforts.

4. What are you going to implement/change in your classroom because of

what have you learned in this institute?

For my Geometry Class
I am already using Jacobs'(3rd ed) text, which I like very much. I plan to review Wu's notes and sequence and re-organize. (e.g. more transformations up before congruence, then similarity) I also plan to incorporate the free hand drawing exercises. May be a little more emphasis on construction.

For my Algebra II Class:
Before we start the Algebra II topics, I plan to review the essential Algebra I concepts with my students. Part of that will include Wu's fraction lessons. (I also plan to study "The Major Topics of School Algebra" by Schmidt and Wu to glean what information I can.

For my middle school and high school classes:
So many ideas! For both clubs but especially my high school club we will make time to practice proofs using Mandelebrot Competition Materials.

For my middle school clubs, I would like to incorporate some of the concepts into club activities (e.g. give students a simple sketch on a grid and tell them to double the size/Fraction Activities.

As I review Wu's notes, I will try to pass on what I can in context.

5. Are you planning to work with colleagues in your school who have not attended the institute? What are your specific plans to implement this?

Yes. First, I would very much like a few of them to attend Dr. Wu's training.

One collegue, Linda John- a physicist, already thinks more like Wu - careful definitions and precision. She may sit in on my classes or substitute if I need her, and has alredy asked that we have tea and talk about summer.

Another colleague, Linda Gerhard, has great influence as a math mentor among the homeschooling community. She works with students of all ages and abilities (gifted → struggling)

6. Do you have to report to an administrator/district/school personnel employee with a summary of what you did during the institute? If you, whom

will you report to and how?

Not exactly, but I will talk with the curriculum coordinator of a local private school I'm associated with and at least recommend that they discard "Discovering Geometry" and replace it with Jacobs' Third edition. (I've been wanting to do this, but now I have Dr. Wu's backing). Also, I may contact the Math Specialist of our Charter School regarding the same idea, and Wu's principles in general. At least I have backing now to do the right thing if I get any opposition (not a problem at this point, but just in case).

7. Additional Comments (use back if necessary):

One good thing about home schooling is the flexibility to make changes w/o hurdles. I would like to share some of Wu's principles and suggestions w/ my home schooling colleagues, perhaps in a workshop format. (If time and energy and opportunity allow).

Evaluation #6

1. What were the benefits of attending this type of institute?

I think that this institute helped me to build a stronger foundation in math. It also made me question many ideas that I knew as 'fact'. By questioning these facts and proving how/why they work, I feel more comfortable going to a deeper level with students. This institute also really made me think about the way I explain things and how I could make them more precise. I think that this will be a great benefit to my classroom because it will make my teaching clearer/more understandable for my students.

2. What improvements do you suggest? Please be specific.

I would like to see more activities/discussion especially during the first week there is a lot of information being given and it is hard to process all of it without having a chance to work with it or talk about it.

3. What would you like to see happen during the Saturday sessions? How would you like them organized? Please be specific. Consider format, topics, etc.

I would like to see the Saturday sessions deal with implementation of these ideas into our classrooms. May be everyone could bring in lessons that they have taught using 'Wu' math to share. I think it would also be helpful to have time to discuss successes/failures when using this in our classrooms.

4. What are you going to implement/change in your classroom because of what have you learned in this institute?

In my classroom I am going to change my approach for teaching fractions. A lot of students already come to 6th grade with a fear of fractions and I think that approaching fractions as numbers will help ease some of that fear. I also really like the model that was used for teaching multiplication of fractions and think it will be a good model to use with the students to teach them why they can just multiply across.

5. Are you planning to work with colleagues in your school who have not attended the institute? What are your specific plans to implement this?

Several teachers at our school have attended Wu and we have talked about strategies that we are going to use to be consistent through out grade levels. We have also discussed strategies we want to share with the other teachers at our school.

6. Do you have to report to an administrator/district/school personnel employee with a summary of what you did during the institute? If you, whom will you report to and how?

No

7. Additional Comments (use back if necessary):

Evaluation #7

1. What were the benefits of attending this type of institute?

The educational benefit for me was having exposed to clear and precise explanation of the purpose of mathematics. The everyday challenge to think logically opened new pathways of thinking and struggling to explore other ways of looking at math problems. I feel invigorated mentally and I have a better understanding concerning where I would like to go from here.

2. What improvements do you suggest? Please be specific.

3. What would you like to see happen during the Saturday sessions? How would you like them organized? Please be specific. Consider format, topics, etc.

More hands on involvement often explanation of each topic.

4. What are you going to implement/change in your classroom because of what have you learned in this institute?

I going to start a math club during my lunch time. I also will connect with my peer who also gained from this time of growth. I have also purchased extra copies and also downloaded copies of Dr Wu's work to share with my colleagues. Everything that I have learned will be used to implement a change in thinking and approach to mathematics at my school.

5. Are you planning to work with colleagues in your school who have not attended the institute? What are your specific plans to implement this?

As I stated in question #4, I will share what I have gained and hopefully next time this program is offered some more of my colleagues will have the pleasure of attending.

6. Do you have to report to an administrator/district/school personnel employee with a summary of what you did during the institute? If you, whom will you report to and how?

I will report to the administrator of my school and it will be with excitement that this institute can profoundly change anyone who is willing to want change and appreciate growth and clarity exponentially.

7. Additional Comments (use back if necessary):

I have had a real mind blowing experience in this institute and I would not be the same or exchange what I have gained for anything but more of what I have experienced.

Evaluation #8

1. What were the benefits of attending this type of institute?

I learned about Wu when I was looking for ways to teach 4th and 5th grade math to 7th graders. After reading Wu's paper on "Fractions, Decimals, ...", I knew I wanted to take the present institute.

The benefits are:

· Learning an approach to teaching math that is sequential, rational and grounded in formal math theories.[1]
· Obtaining new approaches to teaching fractions decimals, rational numbers, translations, dilations, etc, that I think will provide my 7th graders with a firm understanding of these concepts.

2. What improvements do you suggest? Please be specific.

I would prefer that some of the time spent on proofs be traded for work on applications of the concepts we learn.

In the larger room, when Wu spoke softly, I missed much of what he said. In the smaller room, I did not have the same problem.

Overall, the location, facilities and food was excellent.

3. What would you like to see happen during the Saturday sessions? How would you like them organized? Please be specific. Consider format, topics, etc.

1. Extension of how to teach length, area, volume.
2. Group discussion of our successes/failures in teaching these concepts to our students.
3. More instruction on Wu concepts we may be having difficulty with.

4. What are you going to implement/change in your classroom because of what have you learned in this institute?

I will start with introducing use of the number line for fractions, decimals as fractions and positive/negative numbers. Depending on student feedback, I will or will not proceed

[1] It has a lot of similarities to how I teach reading skills to struggling readers.

to other areas such as translations, dilations, similarities.

5. Are you planning to work with colleagues in your school who have not attended the institute? What are your specific plans to implement this?

If I see success with the students I teach then I will work with our principal to determine how and when to introduce the Wu concepts and recommend the institute to other teachers.

6. Do you have to report to an administrator/district/school personnel employee with a summary of what you did during the institute? If you, whom will you report to and how?

We will report our experience and recommendation to our principal.

7. Additional Comments (use back if necessary): .

Evaluation #9 (signed Kelly L.)

1. What were the benefits of attending this type of institute?

The benefits of attending the type of institute are numerous.
1) I got to work with other teachers who teach similar students and who have a comparable background in the context we are supposed to teach. This was helpful because all of the teachers in attendance realize that the way to change the horrible math education that students are getting is to change the teachers.
2) The types of problems that students come across (lack of understanding definitions, the inability to see connections between topics like similar triangles and slope) are the same types of problems I come across. The benefit here is that this fact is explicitly stated.
3) I now understand more clearly the need for teaching clearly, explicitly, and in a hierarchical manner.

2. What improvements do you suggest? Please be specific.

I would find it helpful to have a booklet that lists only the definitions, theorems, postulates and axioms. Often in my frantic note taking I was unable to organize things in a way that made it easy for me to go back and reference. The homework was a little overwhelming most days. I have more empathy for my students. I think 3 or 4 problems per night would be a good amount. I hate to sound petty about homework, but sometimes I just give up.

3. What would you like to see happen during the Saturday sessions? How would you like them organized? Please be specific. Consider format, topics, etc.

I would really like time to talk to other teachers and hear about what is working and not working in classrooms. I would also like to hear about how teachers supplement their textbooks and how they include topics that students need but are not in the curriculum. I would like to have some time to go back and review some of the topics we learned over this institute, especially the use of fractions with the number line.

4. What are you going to implement/change in your classroom because of what have you learned in this institute?

I am going to sit down and compare the list of topics that I am supposed to cover during the school year to what I think students need to know and try to come up with a reasonable compromise of what to teach. I am going to create a month-long (appx.) unit to review/teach for the first time the use of the number line. I am going to rethink the structure of how I ask kids to show the work on their problems specifically how I ask them to justify what they do.

5. Are you planning to work with colleagues in your school who have not attended the institute? What are your specific plans to implement this?

Yes. I plan to share a “recommendations” presentation that I will create. I hope to outline the major changes needed and give realistic suggestions on how to go about change. I hope to have a concrete list of things that it will be possible to change. I already have support from some people in administration and I hope to exploit that.

6. Do you have to report to an administrator/district/school personnel employee with a summary of what you did during the institute? If you, whom will you report to and how?

Yes. I will report to our director of instruction. I plan to create a list of recommendations along with justification for those items. I also plan to create a proposal in a hierarchical order of the things that we need to change. I plan to practice everything with the fact that it will be difficult and that many people will not like it.

7. Additional Comments (use back if necessary):

I can barely begin to say how appreciative I am that I got to attend this institute. I have known for my whole life that the teaching and learning of math had some fundamental flaw because everything has always been presented as an article of faith. I always felt like saying that would have fall on deaf ear because no one seems to want to change. There are so many people who shall think that everything is fine. That is so crazy! Now I feel like at least have some justification for being a proponent for such change even though most people will be very uncomfortable with it. In our most recent text book adoption we were continually told that the teachers should be the ones making the decisions about books we teach from because the teachers are the ones who are the “experts” in teaching math. I was disheartened when our district chose to continue on the same road we have been on. But then I thought why would I expect anything different? Why would teachers ever want to choose to radically change the way they teach? Clearly most don’t. I hope that through logical argument for why teachers (in general) are not the math experts and therefore should not be given the job of deciding on the math curriculum for students. I don't expect to be popular with this statement. I do hope, though that more teachers will be motivated to try hard and recognize their own thinking about the structure of mathematics of K-12 education. Exhale.

Evaluation #10 (This is Larry)

1. What were the benefits of attending this type of institute?

(1) learning the mathematics - or more of the mathematics - that underlines pre-algebra and geometry.

(2) Taking some of what I know to a deeper more coherent level .

(3) Throwing out some rotten disconnected, less coherent rationales I had used to explain things to students, colleagues, and myself and replacing them with more precise, consistent, and reasonable explanations.

(4) proofs: experiencing the frustration, hitting the wall, got me ready to hear Wu's insights on the purposeful (on a good day) thrashing and trying stuff that preclude the strategizing that precedes the point-by-point journey from A to B.

(5) learning about learning about math and about learning math. Clarity and precision are things I'm not good at (yet), but I know I'm getting better - thanks to this institute.

2. What improvements do you suggest? Please be specific.

I can't think of any improvements. The organization and pacing I thought were good. For the proofs some intermediate canonical examples fleshing out the process of arriving at a proof might really help.

Point A (given) Point B (destination) somewhat chaotic thrashing as the problem is encountered What to do now? clear description of problem, sketch, purpose develops, definitions, theorems, light bulb, strategy emerges, outline of proof distilled, write clear proof with full discussion of cases and clear rationale for each step.

The tense succinct excellence of a fully precise, entirely correct proof often reminds me of the glass mountain fairy tale characters we required to climb - or of some landscape or country to arid or airless to live in. Wu and Sunil's patient explanations helped me start to see the process/journey on the way to the brilliant, jewel-like hardness of a properly written proof. (Not that I can write them yet, but I'm sure I'm making progress.) Also come to think of it there were lot of typos in the notes. that could have been caught by some proof reading. I'd be glad to volunteer.

3. What would you like to see happen during the Saturday sessions? How

would you like them organized? Please be specific. Consider format, topics, etc.

Saturday sessions - since we've growing more spread out (San Bernardino, CA to Seattle, WA to New York City) - should have some web aspects to enable people to participate distantly and asynchronously. It would be great to record sessions with some sort of digital, voice-activated audio recording - video, of course, would be even better. May be we can figure out some interactive videoconferencing setup.

Collecting electronic documents pertinent to Wu's Institutes would, I think, be generally useful.

Also collectively electronic documents participants have developed to their classrooms would be useful too.

If you would like for these last two to happen, I have the time, the motive, and the opportunity and would be glad to volunteer.

Also - for Saturday sessions or for sometime - I'd like to be in on a session where we detail the classroom connections of linear equations with similar triangles. That is, activities and lessons.

4. What are you going to implement/change in your classroom because of what have you learned in this institute?

Transformations: basic isometries and dilations

I plan on putting together some animations and short videos of things I've learned in these past 3 weeks:

Powerpoints
GeoGebra
CaR
UCB logo
Videos captured on document camera of work with transparencies and pattern paper and collecting them in a hypertext document 1 at least for my own edification. When I get something that Betty thinks is any good, I'll send it to Wu and see what he thinks.

5. Are you planning to work with colleagues in your school who have not

attended the institute? What are your specific plans to implement this?

Yes

I'm planning on doing more professional development classes in math during the next school year.

I hope to work with elementary school and middle school teachers in Rogue Ruth School District.

I plan to expand the online resources and links I have been compiling at www.soesd.k12.or.us/math/ma

Time permitting, I may do some tutoring of highly motivated students who want to understand math but for whom nothing seems to click.

6. Do you have to report to an administrator/district/school personnel employee with a summary of what you did during the institute? If you, whom will you report to and how?

No.

7. Additional Comments (use back if necessary):

I am very thankful and grateful to have been able to attend this summer. It was truly (once again!) the chance of a lifetime.

Evaluation #11

1. What were the benefits of attending this type of institute?

The benefits of this type of institute is in learning math content from a professional mathematician. Deepening my own understanding of math, I know will improve my teaching and benefit my students. The 3 weeks of intense study is beneficial in being able to digest and process the information in order to learn it. The diverse participants in the institute was a great factor in keeping things interesting and energized (lots of levels of experience too) The small groups were beneficial and a safe place for questions. Lecture format following the lecture notes but not being exactly the same was very helpful.

2. What improvements do you suggest? Please be specific.

I wondered sometimes the specific purposes of some of the homework problems. So may be some rationale included with solutions.

A bit of clarification on the math that is "canonical" and the math that is Wu's preferable take for K thro 12. It would help in talking with my colleagues and convincing them about a very different way to look at some "traditional" math.

3. What would you like to see happen during the Saturday sessions? How would you like them organized? Please be specific. Consider format, topics, etc.

A discussion of lessons that teachers are doing that incorporate the things learned in the institute and adaptations to curriculum.

Discussion about how to work within the systems of our district.

Discussion about how to answer students (and ourselves) regarding lessons, skills and concepts.

Discussion of how to adapt to our classes having students with wide range of abilities.

I like when Wu deconstruct a textbook lesson to show us where the math errors are. We can learn to recognize that type of misinformation and either correct it (or eliminate it.)

4. What are you going to implement/change in your classroom because of

what have you learned in this institute?

I am going to implement more trust in my students and really believe that they do want to understand reasonable explanations. I will, now, more intentionally refer to definitions and previous knowledge to make students aware and remind myself that understanding is built like a structure. (Not just gathered up as a basket of fruit.)

5. Are you planning to work with colleagues in your school who have not attended the institute? What are your specific plans to implement this?

I will be working with colleagues who have no knowledge of the institute. But I will be sharing a lot of ideas with them during our professional learning team mornings. As we plan together in teaching our units, I can give some input on topics related to what I've learned at the institute.

6. Do you have to report to an administrator/district/school personnel employee with a summary of what you did during the institute? If you, whom will you report to and how?

No. I do not need to report. But I do plan to meet with a colleague who used to work in the district office in curriculum development. She is a high school teacher but is intent in helping to rebuild the K to 6 math program in order to impact the secondary program.

7. Additional Comments (use back if necessary):

Evaluation #12 (signed Jake Disston)

1. What were the benefits of attending this type of institute?

I really enjoyed the whole institute the time spent developing the ideas completely and on building the tools (ie: various proof strategies, vocabulary etc) necessary to see how and why mathematics is done correctly. Having facilitated some P.D. myself and knowing how important it is to build a community of learners (much like it is IMP in our classrooms) I was very pleased at how strong this community seemed. We were learning together despite all coming from different grade levels, comfort levels and experiences. Sort of an existence proof for productive learning in a heterogeneous setting w/ very rigorous high level content.

2. What improvements do you suggest? Please be specific.

I feel like I learned most/best when I had opportunities to talk to a neighbor to test my understanding by having to explain it to someone else. There were times when we did less of this which means that most people in the room dont have this opportunity only the few who are called on to answer questions or who raise their own questions to the teacher are actually forced to articulate.

If possible - build on some opportunities for small group discussions.

3. What would you like to see happen during the Saturday sessions? How would you like them organized? Please be specific. Consider format, topics, etc.

I would like to attempt to map the set of ideas/concepts/skills/activities that were presented during the institute so that we can consider which subsets would be 'successful' versions to present to students and which would not. In other words, it would be helpful to work w/others to figure out what big ideas need to be presented formally and which informally so that students learn what we want them to.

4. What are you going to implement/change in your classroom because of what have you learned in this institute?

(1) Never use a book that presents an idea in 5 pages where it can be done in 2 lines.
(2) Definitions Definitions Definitions
(3) <u>connections</u> b/w ideas and what ideas are for. We build/learn the ideas to build/learn

other ideas. Too much of the math studied in 7th grade is presented as disjoint, discrete, disconnected tidbits. We need to figure out how to demonstrate the connected structure if we want students to have a chance at making sense.

5. Are you planning to work with colleagues in your school who have not attended the institute? What are your specific plans to implement this?

Yes - We work together quite closely through lesson study. The things that I have learned with fit nicely on to our lesson study structure - we meet regularly to share new ideas, discuss and agree on a research topic, and design and implement a lesson that we all observe being taught so we can debrief it together. I'm very interested in working w/ my colleagues to figure out how to do fractions and rational #s better in 7th and 8th grade when it has been done so poorly in lower grades. ie: What is the <u>best</u> we can expect to get done w/ limited time in 7th/8th and how can we do it. Specifically - how can we use the # line when it is not universally used in K-8 in our district?

6. Do you have to report to an administrator/district/school personnel employee with a summary of what you did during the institute? If you, whom will you report to and how?

$\emptyset$

7. Additional Comments (use back if necessary):

I came here very interested to experience Wu's workshop. To be honest, among many of my mentors from Tolman Hall of other organizations focused on improving teaching and learning of school math, Wu has a bad reputation. I'm not one to pass judgement based on what other people tell me so in part I came here because I wanted to judge for myself. (and I wanted to know what I didn't know about fractions).

Happily, I have found the experience very rewarding, both in terms of the fraction/geometry learning, but also in terms of hearing what Wu's ideas about learning are (both in the classroom and for teachers). And - not seeing very much conflict btw what Wu advocates for and what my other mentors believe is important in education.

I admire and appreciate very much Wu's complete and unflappable commitment to figuring out for himself, and therefore to helping the education community in figuring out how to change in ways that will benefit all students. The criticisms I've heard of Wu's ideas are insignificant in light of passion that he brings to the challenge and the vision that he has for the direction we need to go. I've learned a lot. Thanks.

Evaluation #13 (Guess: Bill's)

1. What were the benefits of attending this type of institute?

My purpose in attending this institute was to deepen my math thinking. I certainly have learned a more disciplined approch to teaching/learning middle school math. I have acquired greater facility and confidence with logical progression of mathematical relationships especially as they are represented in the number line. I will now be a forceful presenter of the idea that "everything begins with 1". My students will hear that message from me and, hopefully, internalize it more than ever.

2. What improvements do you suggest? Please be specific.

As I have repeated on comment cards there needs to be more time for participants to work cooperatively to solve problems. I am a big believer in think-pair-share. We need to practice this strategy as participants and workshop leaders. It got better as we got to know each other, especially during the third week.

3. What would you like to see happen during the Saturday sessions? How would you like them organized? Please be specific. Consider format, topics, etc.

Prior to the sessions I would like to receive questionnaire so that I may specify what I am currently teaching and my current needs for further development. Responses could be sorted and group so that small groups could collaborate to discuss issues that come up.

I would like to look at problem solving strategies. How are problems introduced, how are the solutions strategies scaffolded. How is the mathematical idea(s) then arrived at in a classroom situation with young students.

Differentiated teaching strategies.

4. What are you going to implement/change in your classroom because of what have you learned in this institute?

I use Everyday Math. I am concerned that there are more standards and pacing is quick for me to give appropriate attention to all of them. I organize my class around teacher directed strategies emphasizing mental math and concept development at the manipulative and pictorial level. For some activities students work in small groups. They also play various strategy games associated with particular unit lessons.

During my lessons on fractions and geometry I plan to place increase emphasis on developing the use of the number line. I have increased my own facility with using it during this workshop. I currently teach my students to organize their patterns in T-charts and tables. The number line will be a further tool for clarifying number relationships.

We need to develop geometric ideas further. I will use the informal strategies especially constructions with compass and ruler more deeply than before.

5. Are you planning to work with colleagues in your school who have not attended the institute? What are your specific plans to implement this?

This has been a real challenge for me. I attend professional development programs where highly motivated teachers are willing to collaborate and share. Unfortunately, the only teachers at my school (K-6) who are willing to collaborate are groups in the lower grades. I will try, once again this year, to work with grades 4, 5, 6, to develop some common purpose and organize around teaching particular math standards. Never give up.

6. Do you have to report to an administrator/district/school personnel employee with a summary of what you did during the institute? If you, whom will you report to and how?

My principal is very supportive. He has sympathy with my teaching strategies. I will discuss what I bring from this workshop with him in hopes that he will follow up and encourage other teachers to adopt strategies that can increase mathematical understanding.

7. Additional Comments (use back if necessary):

Perhaps we will find time to discuss the way things are taught. I feel that any teacher "owns" his or her methods. Unfortunately, I do not respond well to the argumentative nature of this class. I went into teaching, because I believe that there is a better way than the directed teacher - student authoritarian model. I realize that there are times when top-dowm teaching is necessary. However, I have witnessed too frequent occasions when Wu asked a question and there was absolute silence among us. This should be a signal to him that he needs to find another way to engage us.

Evaluation #14

1. What were the benefits of attending this type of institute?

I understand Math a "little" more. Actually, I am more than confident in teaching the concepts now that I have the background. Definitely I will revise my teaching strategy. I wish I attended the institute on "whole #s" last year. I got so much in just 3 weeks.

2. What improvements do you suggest? Please be specific.

None.

I liked the overall schedule for everyday; and the topics were presented in a manner that was very easy to follow.

Breakfast and Lunch were awesome!

3. What would you like to see happen during the Saturday sessions? How would you like them organized? Please be specific. Consider format, topics, etc.

Missing session ⇒ More lecture on length/area (ie. area formulas)

Group discussions ⇒ Discussions of how some of us implement what we've learned in the institute into our classroom.

After break and lunch ⇒ Advices of how we could approach other topics (not presented in the institute).

4. What are you going to implement/change in your classroom because of what have you learned in this institute?

I skipped the basic isometries every year. Now I see that it is very important to teach the students this concept. I am very excited to implement Chap. 4 into the curriculum, and definitely do this chap. 4 before congruency/similarity/slope.

Gosh, I will try to implement almost everything that I have learned in this institute ⇒ it was an eye opening for me.

5. Are you planning to work with colleagues in your school who have not attended the institute? What are your specific plans to implement this?

Yes..

I would like to talk to 4 - 6th grade teachers about the "number line". Our students panic when they see the number line → Thus they are very uncomfortable when it comes to coordinate plane. <u>Fraction</u> is another one!

6. Do you have to report to an administrator/district/school personnel employee with a summary of what you did during the institute? If you, whom will you report to and how?

No

7. Additional Comments (use back if necessary):

I am so glad that I was given the chance to learn "math"! Thank you!

Evaluation #15

1. What were the benefits of attending this type of institute?

1) Refresh basic concepts and definitions.
2) Correct mis-directed ideas of teaching some concepts.
3) Keeping mind fresh during long summer vacation.
4) Going the next step further after the Number Sense Institute.
5) Learning Greek Letter.
6) Working with teachers from around the country

2. What improvements do you suggest? Please be specific.

Go more slowly in explaining how to construct proofs. Early proofs during the institute were done too quickly, which made it difficult to reproduce or explain on homework. When proofs were done slowly and explained in more detail, it was easier to understand. Almost <u>too</u> much info. to digest in the short amount of time in class.

3. What would you like to see happen during the Saturday sessions? How would you like them organized? Please be specific. Consider format, topics, etc.

4. What are you going to implement/change in your classroom because of what have you learned in this institute?

More definitions, More use of Assoc., Dist., and Comm. Laws, Clearer explanations of addition and multiplication of fractions. Possibly use of * instead of negative numbers. Dilation instead of scale. More emphasis on similar $\triangle$.

5. Are you planning to work with colleagues in your school who have not attended the institute? What are your specific plans to implement this?

I am already working with some, and others are too stubborn. I will follow up on students progress from previous years classes. We have monthly dept. and grade level mtgs. to discuss progress.

6. Do you have to report to an administrator/district/school personnel employee with a summary of what you did during the institute? If you, whom will you report to and how?

No, but I have continued to make my principal aware of these institutes and the PD hours count for our QEIA grant.

7. Additional Comments (use back if necessary):

Evaluation #16

1. What were the benefits of attending this type of institute?

To gain a deeper understanding of the reasoning behind the algorithms we teach. I think I will be able to differentiate my math lessons to my students with higher (more advanced) abilities and understanding. I think I will be able to better explain 'why' behind what we learn in mathematics. Teachers do need more rigorous, research-based knowledge of specific content areas, specifically math. We need to expand our reasoning skills, and language skills in math just as our students do.

2. What improvements do you suggest? Please be specific.

A description of a clean and concise research-based sequence for teaching math at 6th and 7th grade. Less convoluted discussions and homework questions. The questions such as "how would you explain 'x' to a 7th grader" were good. Less proofs in lecture and homework. Clearer descriptions of how to teach these concepts at the level we teach. Some of the reasoning was way to complex to be utilized appropriately in a middle school classroom.

3. What would you like to see happen during the Saturday sessions? How would you like them organized? Please be specific. Consider format, topics, etc.

Less lecture and more collaboration with teachers that teach in similar areas. Sharing ideas of what worked and what didn't, and how to do it better next time. Time for reflection on practices, and having some time to ask Wu specific questions about how we could do it better if our lesson falls flat. A format of evenly distributed time with breaks works best for my attention span.

4. What are you going to implement/change in your classroom because of what have you learned in this institute?

I will use more precise language, definitions, and use the theorems for the touch stones of my teaching methodology. I might do repetition. I will hope to investigate the main ideas obtained here at this institute so I can trim the fat, and not have to teach extraneous information that may not be helpful to my students in the long run (ie LCD) etc. I would like to be able to get my students to ask the question "why?" in mathematics.

5. Are you planning to work with colleagues in your school who have not attended the institute? What are your specific plans to implement this?

I do plan to share information with my colleagues. I would have liked a concise list of suggested "Do's and Don'ts", but I will have to go through the book and synthesize the information myself. I would like to share ideas of how to integrate these concepts in teaching after the saturday sessions. I meet with my colleagues 3 times a week so there will be plenty of opportunity to share ideas and information.

6. Do you have to report to an administrator/district/school personnel employee with a summary of what you did during the institute? If you, whom will you report to and how?

I do not have to report.

7. Additional Comments (use back if necessary):

At times it might have been nice to have a little less lecture format. May be add a few more hands-on activities.

Evaluation #17 (My guess is Prema. The comment about the 6-12 school is the giveaway.)

1. What were the benefits of attending this type of institute?

I am so grateful for the knowledge that I have gained here. Unlike other professional development institutes where "activities" and "lessons" are paramount, here I learned the math necessary to really teach well. Moreover, even though I was always uncomfortable with the way math is taught these days in most math classrooms, and always tried to do something different, I realize now that I still operated with a certain blindness. After this institute, I am really beginning to see the STRUCTURE of math, the importance of sequencing and the insistence of precision, definitions, and theorems. It has truly changed the way I see math and I believe the way I will teach math from this day forth.

2. What improvements do you suggest? Please be specific.

- perhaps as part of each nights homework, include one question on "solve and explain this to a 7th grader ..." and then INSTEAD of the morning do now problem we could share our answers with a partner.

-show some assessment questions from NAEP, TIMMS that are "wrong" since many of us create our own assessment in our classrooms. I'd like to get better at this and see what are examples of wrong questions.

3. What would you like to see happen during the Saturday sessions? How would you like them organized? Please be specific. Consider format, topics, etc.

(1) share and/or develop meaningful assessment questions on fractions, rational numbers both formative and summative. We can bring possible questions for a particular topic, brainstorm/discuss whether they are really good for their purpose, revise them.

(2) share particular lessons that worked well, for example, I would really like to know how each of us are going to teach $m \div n = \frac{m}{n}$; what worked when we did it, what were confusions, etc.

4. What are you going to implement/change in your classroom because of what have you learned in this institute?

(1) change the order of my curriculum units so that each concept builds upon the previous in a correct mathematical hierarchy

(2) Insist on definitions that are precise and ensure that these definitions are regarded as IMPORTANT

(3) use the theorems (without necessarily calling them theorems) and help my students see that the theorems and definitions are NOT simply words to be memorized, but rather provide a fundamental basis for the math they are doing

(4) teach dilation! teach fractions before decimals! teach with more reference to the number line!

5. Are you planning to work with colleagues in your school who have not attended the institute? What are your specific plans to implement this?

I am now in a grade 6 - grade 12 school. We have math department meetings each month, although there is ONLY one math teacher per grade. I would like to bring back the knowledge to my colleagues in the hopes of eventually developing a seamless structure of math teaching 6-12 at the school. Four out of the six teacher in math will be new to the school this next year so I think it will be great if we can really get to the "same page" so to speak.

6. Do you have to report to an administrator/district/school personnel employee with a summary of what you did during the institute? If you, whom will you report to and how?

I do not have to do this, but I expect that I will talk to my principal and my buildings science/math coach about my experience here. My principal was very interested in my math class this year so I believe that she will be quite keen on seeing how my math teaching changes/develops in the next year.

7. Additional Comments (use back if necessary):

THANK YOU. These two words do not suffice really for the knowledge that I have gained, but therein lies the limit of language!

Evaluation #18

1. What were the benefits of attending this type of institute?

I feel this strengthened my own math knowledge. Being able to prove something from a "given" is very important.I think my brain de-rusted some & I remembered material from my very old Geometry classes. This, of course, helps me teaching middle school knoweing where they are going next.

2. What improvements do you suggest? Please be specific.

I know the proofs are important by they go so long....I think giving the class short problems with attention to proofs is very helpful in bringing more students into the lessons. Teach us how to do the proofs by giving short easy ones first and repeating it until everyone can do one (very simple repetitive one) on their own!

3. What would you like to see happen during the Saturday sessions? How would you like them organized? Please be specific. Consider format, topics, etc.

(1) I would like to see a sharing of how we used this material in our classroom.
(2) Perhaps we could look a common "textbook" lesson together and discuss how to make it more correct for teaching and expand on it.
(3) Need help on surface area (expanding lesson) and volume of prisms, pyramids, and cones.

4. What are you going to implement/change in your classroom because of what have you learned in this institute?

A few things:
(1) Doing fraction operations on a number line (2/3 x 3/4 is 2 parts of 3/4 divided into 3 sections!) Also just showing the fraction bars that show 3/4=9/12 etc.
(2) Using dilation to introduce scale drawings. This will particularly benefit the 6th graders and be useful to 7th.
(3) When we get to congruent figures I will have them use rotation to help them picture the congruencies. I will also use ASA, SSS, SAS.

5. Are you planning to work with colleagues in your school who have not attended the institute? What are your specific plans to implement this?

I will show my 6th grade teacher colleague the number line for fraction operations. We develop lessons together often. *Also using dilations before proportions on scale drawings. I will show my 7th grade teacher colleague
(1) the first geometry exercises we did in class together
(2) information on rottionsin use with SAS, ASA, SSS.

6. Do you have to report to an administrator/district/school personnel employee with a summary of what you did during the institute? If you, whom will you report to and how?

I don't <u>have</u> to report but I will give a summary in our math dept. meeting to give them excerpts from parts I think they will use. My principal was a math teacher with us before, and she will certainly want to hear about this :-)

7. Additional Comments (use back if necessary):

Just thank you for all of your time and efforts.

Evaluation #19

1. What were the benefits of attending this type of institute?

The depth of mathematical study during each day was above and beyond any other course of study I've ever been part of. That was beneficial. Three weeks of this is unmatched. Wu really made me aware of the gaps in my teaching of mathematics. He was able to guide us through topics: positive/neg fractions, geometry and congruence and connect each to the whole middle school curriculum. Fantastic. The setting and facilities at MSRI are beautiful and conducive to "higher thinking". It was a special opportunity.

2. What improvements do you suggest? Please be specific.

I cannot really offer any suggestions for improvement. Each detail of the institute, from parking to meals to the comfortable accommodations were fine. The learning schedule, 6 hour lecture, 1.5 hour small group and homework was well balanced.

3. What would you like to see happen during the Saturday sessions? How would you like them organized? Please be specific. Consider format, topics, etc.

Saturday sessions will have to include time spent in small groups and large groups, so that individuals get a chance to talk. Perhaps it would also help if there were "forums" online where we could carry on preliminary dialogue leading up to the SAT sessions. If the SAT sessions were just left to extemporaneous conversations then there is the chance they would fail. Some balance is needed between too much and not enough structure.

4. What are you going to implement/change in your classroom because of what have you learned in this institute?

I will start by conducting more careful planning and consideration of the things I teach. Obviously I will place more importance on structure and definitions hoping to run a "thread" through the varieties of topics. I plan to continue to read and study the notes. Continue searching for age appropriate ways to communicate precision and clarity.

5. Are you planning to work with colleagues in your school who have not attended the institute? What are your specific plans to implement this?

Yes. During our flex days, I plan on engaging in discussions of lessons and approaches to teaching and planning. Perhaps begin a lesson study group.

6. Do you have to report to an administrator/district/school personnel employee with a summary of what you did during the institute? If you, whom will you report to and how?

I came here on my own. My administrator was not part of it. He wants what is best for kids. He may not accept wholesale Wu's more rigorous approach, but I anticipate that he will allow me the opportunity to try. He asked me to come and talk with him about some new courses the school is trying. I expect to make a case then.

7. Additional Comments (use back if necessary):

Evaluation #20

1. What were the benefits of attending this type of institute?

* depth of content knowledge increase
* knowledge of prior and following grade level content
* understanding the precision necessary in mathematics.
* understood the true meaning of mathematical concepts are related
* Being taught by mathematician
* writing my first proof!
* Feeling more confident in content knowledge

2. What improvements do you suggest? Please be specific.

* I think that all small groups should be led by mathematicians
Support: in Sunil's group I found that asking questions and problems were very helpful.
→ the groups were to discuss content and should be lead by mathematicians
* Conversely, if the groups are to discuss implementation in the classroom then they should be lead by classroom teachers (I do not recommend this ...) Teachers do this informally all day long.
* From Day 1 or before Emphasize the helpfulness of reading the notes. It should be part of the homework.
* Print out list of all Definitions and a list of all theorems as a tool kit (writing notes, and understanding content while writing a cheat sheet was hard)
* Last day should be used for discussion of classroom implementation, class time breakdown, small groups design lessons about topics learned to see how others would teach the same content. Time to process what we will do in/or not do in our districts. Wu's feedback on these ideas.

3. What would you like to see happen during the Saturday sessions? How would you like them organized? Please be specific. Consider format, topics, etc.

I - Discuss classroom structures, ideas for organization, time management, supplementals.

II - Discussion of similarity, activities Concept development

III - Develop a lesson on similarity (or some topic) together as a team that can be adapted for various grade levels. Teach it before the next Saturday.

IV - Discuss success/failure of lesson improvements.

V - Responses from other teachers, district responses, practical approaches to furthering implementation

4. What are you going to implement/change in your classroom because of what have you learned in this institute?

* Emphasize precision and definition
* Encourage "why?"
* Perpetuate the philosophy that math is hard work, there in lies the fact "learning is not learning without frustration".
* Teach fractions with number line and "Wu" methodology
* Sequence Transformations → Dilations → Congruence → Similarity →Slope

5. Are you planning to work with colleagues in your school who have not attended the institute? What are your specific plans to implement this?

Yes, beginning with middle school staff, those who are interested in the fraction number line model. From there to the elementary staff for those are interested.

6. Do you have to report to an administrator/district/school personnel employee with a summary of what you did during the institute? If you, whom will you report to and how?

Yes, I will make a list of recommendations in regards to curriculum in the district, to the head of instruction.

7. Additional Comments (use back if necessary):

Evaluation #21 (This is Jesse)

1. What were the benefits of attending this type of institute?

The main benefit to me was being exposed to the method and approach of a "real" mathematician → carefully and precisely defining terms and procedures, and axiomatically building of a framework upon which to create a coherent and mathematical system of theorems.

The repeated mantra that mathematics is a logical whole rather than a set of disjoint skills and content is one I would very much like to continue to explore, internalize, and then transmit to my students.

2. What improvements do you suggest? Please be specific.

Given that institute participants are all at "different pages" with respect to preperation, backgroud and fluency with the material, I beleive there is value in establishing norms for the class. That is, obviously it is Wu's baby, and he can be "on" as long as he see's fit. But as for the students I would have liked a norm of "smell the air" - these were people who don't speak, comment, question even once - and others who took up more than their share.

I was more able to follow lectures when I was <u>not</u> taking notes - For others the reverse might be true.

More "turn and talk" time

More "Joe thinks this is , Tom thinks it isn't ... a congruence, e.g., with whom do you agree and why?

3. What would you like to see happen during the Saturday sessions? How would you like them organized? Please be specific. Consider format, topics, etc.

* in general it should be about how the material we learned here is coming alive in the classroom.
* It would be beneficial to know/pick a specific topic or concept that we do teach, and each T bring in materials/lesson design they might use to teach that concept, and then share and discuss how this fits into the "Wu structure".

4. What are you going to implement/change in your classroom because of what have you learned in this institute?

* more precise definitions
* more number line applications
* more time on the basic isometries, and dilation
* more explicitly/rigorous demand on students justifying their statements with established math "facts" (theorems)

5. Are you planning to work with colleagues in your school who have not attended the institute? What are your specific plans to implement this?

Jake and I will get together and present to our dept. I will also work with the other 7th grade teacher (to be hired)

In planning the year I'll sit down with:
* textbook
* pacing guide
* district-Q, sem. Q, final assessments
and see how best to integrate the material

6. Do you have to report to an administrator/district/school personnel employee with a summary of what you did during the institute? If you, whom will you report to and how?

$\emptyset$

7. Additional Comments (use back if necessary):

* Much appreciation to Wu, Sunil, Stepjanee and Winnie for all their hard work.

* Again more interaction between/among students (us) (I think) would result in greater learning.

* I know it was explicitly stated that "implementation" was <u>NOT</u> the purpose of the institute, but I think providing some time for us to reflect/discuss how we will bring this to the classroom will help us learn more here.

Evaluation #22 (This is Priscilla)

1. What were the benefits of attending this type of institute?

First let me say there were so many benefits that I would need several sheets of paper to detail. That being said, here are a few:

1) I finally see the K-7/8 math instruction as the foundation for algebra - the hierarchial nature of mathematics has never been so clear.

2) Precise definitions are so important to not just memorize (which actually is helpful) but to understand and point students to in order to build the foundation

3) Now I understand the <u>HOW</u> and <u>WHY</u> behind moving students in gr. 5 - 7/8 to transition into greater levels of abstract reasoning.

4) My own mathematical content knowledge has been strengthened so much! I have more to master and practice, but I see the path.

5) We have actually had instruction from a <u>mathematics</u> professor who understands teaching and a master teacher himself.

6) Wu had excellent support teachers who helped in so many ways. "Team Wu" made this institute an <u>excellent</u> and <u>worthwhile</u> P.D. opportunity - Truly a blessing!

2. What improvements do you suggest? Please be specific.

Q. Is there a way to get the answers to the other questions that were not assigned? I want to go home and work through these problems, but I am not sure I will get the answers w/out having help. I know that is so much work, but I thought I would ask.

3. What would you like to see happen during the Saturday sessions? How would you like them organized? Please be specific. Consider format, topics, etc.

* Further discussion on similarity of $\triangle$s/congruence the importance of this in the context of middle school mathematics instruction/ and looking ahead towards high school ...
* More discussion on "conceptual understanding" vs "basic skills" and direct instruction vs discovery learning in math
* Where is the balance in pedagogy that truly honors the hierarchical nature of mathe-

matics?
* How are people teaching the fraction/decimal/%/rate/ratio material in gr. 4 - 7? In other words, what does it look like in the classroom on a week by week basis? :-) → Examples of taking Wu's materials and using it.
* How to develop meaningful assessment questions related to what we want our students to learn on these topics.

4. What are you going to implement/change in your classroom because of what have you learned in this institute?

Wu First, thank you for sharing the Whole Numbers materials from the 2008 institute. Now that I have a BIG picture of the hierarchical nature of gr. 5 - 7 mathematics, I will be able to truly make meaningful changes in the sequencing of instruction in grade 4 (which I an teaching next yr.) Also, I will have a number line pasted from Day ! and I will be encouraging other teachers in my building (and district) to begin using this universal mathematical tool. In addition what I have learned about fractions ha been invaluable! I finally understand this topic myself and I cant wait to get home and study Wu's notes again (and practice) so I can solidify my own understanding. As a result my instruction (and my work with other teachers) will benefit my students (and my understanding will allow me to effectively communicate the "WHY" to colleagues.

5. Are you planning to work with colleagues in your school who have not attended the institute? What are your specific plans to implement this?

Yes!

Well, first I will be meeting with one principal of one of our elementary schools who has the Elem. Math Coach last yr. She knw I was coming to this and wants to debrief with me upon my return. Also, I will meet with my own building principal who has been interested in my 'math journey'. In addition, I will be writing a summary report and sending it to our District Curriculum Director, Supt. and School Board members. Finally, I am going to schedule a meeting w/ our WA Asst. Supt. of Schools and go and show him the content that is accessible for teachers to actually strengthen their math content knowledge. (I will be sharing what I have learned with as many people as possible! :-)

Oh - back to colleagues - I am going to ask my principal if he would like me share small "pieces" from the institute w/ our staff as the year progresses. I want to be of resource person and feel that my prior work on our District Math Committee and as a state DD facilitator has given me some credibility. NOW I have the much needed content to bakc it up!

6. Do you have to report to an administrator/district/school personnel employee with a summary of what you did during the institute? If you, whom will you report to and how?

No - but I am going to submit a summary report as a gift :-) (as stated in # 5).

7. Additional Comments (use back if necessary):

I am now so thankful to know and understand (well I am working on this!!) mathematics beyond the grades I teach.

Thank you Wu for working on developing the materials for our class. Such hard work!!

Thank you Sunil, Winnie and Steph for all of your help. You all are incredible and I appreciate your involvement in this endeavor.

* "The most important thing to learn in (a) mathematics class is the ability to sustain sequential thinking."

Favorite Wu Quote!

Evaluation #23 (I guess this is Claudia)

1. What were the benefits of attending this type of institute?

First and foremost taking advantage of Prof. Wu's knowledge and wisdom. He is very patient and very clear. Secondly, I find it fascinating and very helpful to listen to peoples thought process and understanding. Coming to institutes like this not only clears my brain and puts it work but also makes me want to be a better, clearer, and more precise communicator of concepts and ideas.

2. What improvements do you suggest? Please be specific.

I don't know what else better is out there, I'm just discovering the good, so I don't fell I could suggest anything valid. For me it's all great.

3. What would you like to see happen during the Saturday sessions? How would you like them organized? Please be specific. Consider format, topics, etc.

I know there were some topics we didn't do, may be we could start with that. Also, we could ask specific people to make presentations about their programs, books, classes, what they've charged (or not) and then have a discussion and give each other feed back. We could also use this time to maybe do some math curriculum mapping together.

4. What are you going to implement/change in your classroom because of what have you learned in this institute?

I teach K-5, so I will continue with my new fraction lessons - I made a supplement last year for teachers to use in her teaching of fractions -. Additionally, I will work with my teachers (MORE) in the importance of clear and precise definitions. As I said, we will focus on geometry re -mapping in 4th and 5th, and add more of it the right way :-) in primary grades.

5. Are you planning to work with colleagues in your school who have not attended the institute? What are your specific plans to implement this?

I am working with my 4th and 5th grade math teachers (I have 2 classes per grade but in 4th and 5th one of classroom teachers does the math and the other one LA). We started this year (we did 3 mos of fractions) and we'll start geometry in August. I am also going to work with some Geometry teachers (10th grade) from the school district I used (to) work for.

6. Do you have to report to an administrator/district/school personnel employee with a summary of what you did during the institute? If you, whom will you report to and how?

I report to the Director of Studies and the Finance person. I will summarize our 3 weeks by saying it's a breeze of fresh air and that I'm more convinced than before that I don't know any math, but am for sure learning math and especially how to learn it.

7. Additional Comments (use back if necessary):

Evaluation #24

1. What were the benefits of attending this type of institute?

There were many. It has motivated me to get a better understanding of the math I teach and work on improving on how I teach math. I want to now spend time this summer to carefully plan the sequence of the skills I teach to match the logical progression that Wu demonstrated in the institute. It was inspiring to be taught by someone so knowledgeable and passionate about math and reforming math education in K-12 schools. I truly feel lucky to have been given the opportunity to attend.

2. What improvements do you suggest? Please be specific.

3. What would you like to see happen during the Saturday sessions? How would you like them organized? Please be specific. Consider format, topics, etc.

Sharing implementation stories (Eg. lessons that worked well, problems that were encountered, etc)

4. What are you going to implement/change in your classroom because of what have you learned in this institute?

I still need time to figure out, but I will definitely implement a lot of what I have learned at the institute in my class. I plan to re-read the lecture notes and start creating lessons/units based on the material on the book.

5. Are you planning to work with colleagues in your school who have not attended the institute? What are your specific plans to implement this?

Short answer is yes. I will talk informally with them and share (or at least try to) with them what I have learned. My hope is that they will be receptive to also changing some of the ways they teach as well.

6. Do you have to report to an administrator/district/school personnel employee with a summary of what you did during the institute? If you, whom will you report to and how?

No

7. Additional Comments (use back if necessary):

It would be nice if a bank of lessons were created (by attendees) that could be put in a central location - eg. Google Docs.

2010 Mathematical Sciences Research Institute – Undergraduate Program (MSRI-UP)

Final Report

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2010 Mathematical Sciences Research Institute – Undergraduate Program (MSRI-UP)

Final Report

1. Introduction

MSRI-UP continued in 2010, June 12 through July 25, with 18 students studying and researching Elliptic Curves and Applications. The summer program was staffed by lead director Duane Cooper, research leader Edray Goins, postdoctoral fellow Luis Lomelí, and graduate students Kathleen Ansaldi and Ebony Harvey.

The MSRI-UP is a comprehensive program for undergraduates that aims to increase the number of students from underrepresented groups in mathematics graduate programs. MSRI-UP includes summer research opportunities, mentoring, workshops on the graduate school application process, and follow-up support.

The primary objective of the MSRI-UP is to identify talented students, especially those from underrepresented groups, who are interested in mathematics and make available to them meaningful research opportunities, the necessary skills and knowledge to participate in successful collaborations, and a community of academic peers and mentors who can advise, encourage, and support them through a successful graduate program. We achieve this through an intensive six-week summer program of mathematics research and other activities, along with maintenance of relationships with participating students for years beyond the summer program.

The MSRI-UP is coordinated by an experienced team of five directors, Professors Duane Cooper of Morehouse College, Ricardo Cortez of Tulane University, Herbert Medina of Loyola Marymount University, Ivelisse Rubio of the University of Puerto Rico, Río Piedras, and Suzanne Weekes of Worcester Polytechnic Institute, who collaborate ongoingly and who annually rotate direct leadership of the program. The program is supported by the leadership and staff of the Mathematical Sciences Research Institute in Berkeley, site of each summer's six-week program.

During the 2007-2009 summers, 46 students conducted 15 small group research projects in Computational Mathematics, Experimental Mathematics, and Coding Theory. Most MSRI-UP participants who have graduated college proceeded to enter graduate programs in the mathematical sciences. In 2010, 17 undergraduates completed MSRI-UP, having learned about and engaged in research on Elliptic Curves and Applications, led by Professor Edray Goins of Purdue University who has guided the students in conjunction with a postdoctoral fellow and two graduate students—carefully chosen role models—who contribute to the undergraduates' academic, personal, and professional development. In 2011, the MSRI-UP will continue with 18 undergraduates conducting research projects in Mathematical Finance, led by Professor Marcel Blais of Worcester Polytechnic Institute.

3. Recruitment, Application and Admissions Procedures

The co-directors began recruiting for the 2010 MSRI-UP at the annual conference of the Society of Chicanos and Native Americans in Science (SACNAS) in Dallas, Texas in fall of 2009. The co-directors present distributed fliers and talked to dozens of students and faculty about the program. The MSRI-UP home page also provided information about and applications for the program. Recruitment of students also occurred that fall at the National Association of Mathematicians' (NAM's) Undergraduate MATHFest XIX in Washington, D.C.

The co-directors e-mailed flyers to hundreds of mathematicians, to SACNAS members who belong to the mathematics community, to professors who had sent letters of recommendations for students to previous summer programs, and to colleagues in their national professional networks.

[1] Grant number H98230-10-1-0233.

The on-line application, which had a March 1, 2010, due date, consisted of four items: a completed student application form, transcripts, a statement of interest, and a letter of recommendation.[3] The 2010 MSRI-UP received about 120 applications.

The co-directors Cooper, Cortez, Medina, Rubio, and Weekes, reviewed each application and evaluated it using four criteria: 1.) the student's grades in mathematics courses; 2.) the student's mathematical background; 3.) the statement of interest; and 4.) the letter of recommendation. Based on these four criteria, each of the Co-Directors gave each applicant a score between 0 and 10. The scores were summed and averaged, and this score served as the initial measure for evaluating each applicant. The co-directors then proceeded to discuss individual applications and eventually reached a consensus on the eighteen[4] admittees for the program. Two students declined, and the directors replaced them with alternate candidates.

4. Summary of Participant Demographics

Table 1 details some demographic information of the eighteen MSRI-UP students who began the program. The student participants were diverse by race and ethnicity, as well as by the types and geographic regions of their undergraduate institutions. The co-directors paid special attention during the selection process to attain racial and ethnic diversity and gender balance. Achieving this type of diversity and gender balance is important for creating the academic and research environment explained below and for achieving one of the MSRI-UP objectives.

5. Housing and Lodging for the Students

The students were housed in Stern Hall dormitory at the University of California, Berkeley. On weekdays, lunch was served at MSRI. The lunches at MSRI were shared with graduate students, faculty, and teachers participating in other MSRI summer programs. This allowed students to meet mathematicians at different stages of professional development. The students and the program's graduate students had breakfast and dinner at the dining facilities in the dormitories. On occasion, meals were shared by MSRI students and senior staff. Sharing meals with their

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[2] Research Experience for Undergraduates (REU) program grant number DMS-0754872.

[3] Please see http://www.msri.org/up/intropage.

[4] The program is designed for eighteen students and indeed eighteen students began the program. For disciplinary reasons, one student was required to leave the program before its completion.

MSRI-UP peers promoted mathematical discussions and enhanced the collaborative and intellectual environment of MSRI-UP.

Table 1

2010 Mathematical Sciences Research Institute (MSRI-UP)

Student Data

Undergraduate Institution and State		**Gender**	
California State Polytechnic University, Pomona, CA	1	Male	10
Loyola Marymount University, CA	1	Female	8
University of Northern Colorado, CO	1		
Florida A&M University, FL	1		
Morehouse College, GA	1		
Spelman College, GA	2	**Major**	
University of Kansas, KS	1	Mathematics	17
University of Massachusetts, MA	1	Economics	1
Michigan State University, MI	1		
Carleton College, MN	1		
Union College, NJ	1		
Oklahoma State University, OK	1	**Ethnicity**	
Lewis & Clark College, OR	1	Latino	7
Reed College, OR	1	African American	7
University of Puerto Rico at Mayagüez, PR	1	Native American	1
Brown University, RI	1	Asian American	1
Sewanee: University of the South, TN	1	White/Caucasian	2

6. Pre-Research Seminar

During the first two weeks of MSRI-UP, students participated in a pre-research seminar consisting of lectures, tutorials, and problem-solving sessions. Professor Goins planned the seminar so that he could familiarize students with the motivation and fundamental concepts of the field of elliptic curves and also the main techniques that they would need to work on their research topics.

The pre-research phase was conducted in the Baker Board Room, an excellent classroom-type facility at MSRI. Attached, as an appendix to this report, is the program calendar, describing the structure of these first two weeks of the program and the subsequent four weeks.

Some homework assignments during the pre-research seminar were computational in nature. Most students had their own laptop computers; the one who did not was able to borrow one from the MSRI for the duration of the program for use before and during the research projects. Many assignments and projects required that students become familiar and adept at Sage mathematics software system, and written work was submitted using LaTeX. Students also had access to computers in their MSRI offices, but most access the network using their laptops, instead, both on site at the Institute and from the dormitories in the evenings.

7. Research Projects, Technical Reports and MSRI Student Presentations

The focus of MSRI-UP is undergraduate research. After the first two weeks of the program, each student worked exclusively on an undergraduate research project in the field of coding theory that was carefully designed by the seminar leader. Initially, there were six groups of three students, though one group completed the summer as a pair. Students wrote technical reports and presented the results of their research in the MSRI-UP Student Colloquium the last Friday of the program.

During the second week of the program, students received descriptions of their possible research projects. The students did preliminary reading and literature searches on the project topics, and they were requested to rank their top project choices. However, program staff composed the research teams, satisfying student preferences as much as possible while paying attention to interpersonal dynamics that had been observed during the first pre-research seminar.

During the research phase of MSRI-UP, students worked in the offices assigned to them at MSRI. Each research team was assigned a support person from the academic staff of the program. Professor Goins oversaw all the work of all six groups, and he also supervised two teams directly. Postdoctoral fellow Lomelí supervised two research teams, and each graduate student supervised one team. The undergraduates met with their support person for several hours each day, and each team met periodically with Professor Goins to update him and receive guidance.

During the program, MSRI-UP participants were introduced to some of the techniques that are used while conducting successful research in the mathematical sciences. Indeed, students learned to work as part of a research team, develop an effective faculty advisor-student relationship, use computer software as tools, use the Internet as a resource, prepare and deliver an oral presentation, write a mathematics paper (technical report), and use LaTeX, including the Beamer package for presentations.

The outcome of all the students' hard work and dedication (and of course staff support) resulted in six technical reports and an equal number of oral presentations in the Student Colloquium Series. A sample technical report is included as an appendix to this report.

8. Evaluation of Student Work

Close interaction with students allowed the academic staff to give individuals feedback on their work throughout the program. During the pre-research seminar, homework assignments were reviewed by the academic staff and critiqued by peers as students presented solutions to problems daily. During the research phase, each of the six research teams held daily meetings, for which students prepared frequent oral and written progress reports. Professor Goins and either Dr. Lomelí, Ms. Ansaldi, or Ms. Harvey, who were serving as support for the research groups, were present at the daily meetings.

Indeed, the program's academic staff gave students written feedback on drafts of their technical reports so that the finished product would be formatted as a professional publication. The academic staff also helped the students prepare slides for their oral presentation.

Program staff met at the program's end to assess the undergraduate performance at the program. These descriptive staff evaluations of the students will be kept by MSRI-UP for purposes of long-term evaluation of program effectiveness.

9. Colloquium Series

The 2010 MSRI-UP hosted five mathematicians for a colloquium series: Herbert Medina, Loyola Marymount University; Alejandra Alvarado, University of Arizona; Stephanie Somersille, University of Texas; Suzanne Weekes, Worcester Polytechnic Institute; and Emille Davie, California State Polytechnic University, Pomona. The colloquium series stimulated the mathematical interests of the students and gave them a glimpse of current mathematical research. In addition to this, the speakers provided the students with additional role models and expanded their network of mentors. The speakers' schedules were arranged to maximize opportunities for them to engage the undergraduates in informal conversation, and many students took advantage of the opportunity to listen, ask, and learn.

The program also was fortunate to coincide with a two-week Sage Days graduate workshop at MSRI on Computing with Elliptic Curves. Students were able to meet active researchers studying elliptic curves, and they attended a presentation by invited guest Professor Ken Ribet from the University of California, Berkeley.

10. Graduate School Workshops and Individual Academic Advising of MSRI-UP Students

Dr. Colette Patt, Director of Diversity Programs in the Physical Sciences at the University of California, Berkeley visited MSRI-UP and gave a workshop on applying for graduate school and attaining fellowship funding for graduate school. The workshop addressed questions/issues such as the significant differences between masters and doctoral programs, the funding opportunities available for most graduate programs, and the benefits of obtaining a graduate degree. In addition to this basic information, Dr. Patt also presented successful techniques for applying to graduate school. She discussed the elements that constitute a good statement of purpose, the types of professors from whom one should seek letters of recommendation, and successful techniques for addressing not-so-stellar semesters. Dr. Patt also discussed successful strategies for compiling a winning national fellowship application. She also provided the students with related written material. Her presentation and the information she provided were *very* well received by the program students.

11. Additional Workshops & Panels

The program held workshops that were devoted to the development of skills that are important to every mathematician. One was devoted to learning LaTeX, the typesetting program most widely used by mathematicians. This workshop was designed and run by MSRI-UP Co-director Herbert Medina during his first-week visit to the program. These skills were needed as MSRI-UP students prepared their technical report and transparencies using LaTeX, gave an end-of-program oral presentation using Beamer presentation slides, and used LaTeX to prepare their research posters.

The program presented a panel discussion by current graduate students for the undergraduates. The panel was moderated by the program's two graduate student assistants, and four mathematics and statistics doctoral students at various stages served, one from Purdue University, a student of Professor Goins, and three from the University of California, Berkeley. They spoke about their graduate-school experiences with the aim of "demystifying graduate school in mathematics." They provided insights on selecting a graduate department and succeeding in it.

A presentations workshop was conducted to share information about the three ways that students were preparing to communicate their summer's work—on a poster, in oral presentation, and in written technical report. Student teams were assigned selected readings on each method and asked to prepare for the group at large. Though the workshop was somewhat valuable, feedback from the student evaluations suggest that it was less helpful than the others, so in future summers it may be better to improve this panel or discard it for a mathematics career or professional panel.

12. Recreational/Cultural Activities

In addition to all the academic activities described above, MSRI-UP students were treated to several recreational activities. These included visits to nearby San Francisco, Santa Cruz, and Marin County, an Oakland Athletics baseball game, and a kayaking excursion on the Oakland estuary. These carefully-planned recreational and cultural activities were essential to MSRI-UP's success, as they gave students the opportunity to put mathematics aside for a few hours so that they could come back later to their work with renewed vigor: They also helped to build the MSRI-UP mentored community, as all staff participated in the activities with the students.

13. Program Evaluation During MSRI-UP

Informal formative evaluation in the program started the first day of the program through conversations with students and staff. Frequently during the program, Professor Cooper met individually with each one of the students and staff of the program, conducting extensive discussions with Professor Goins to learn about and share opinions regarding the research component. During the meetings with staff and students, the Director had the opportunity to have more close contact with the students and staff, to listen to individual concerns, and to provide individual mentoring to the students. The staff's close interaction—especially the graduate assistants—with the students enabled them to gather informal feedback that also led to adjustments to improve the program.

The program staff had regular weekly meetings to discuss individual and group progress, and they held several impromptu lunch or other daytime meetings as issues arose that would benefit from immediate discussion and resolution. At the final staff meeting, individual student performances were discussed at length.

14. End-of-Program Evaluation

Each MSRI-UP student was required to complete a comprehensive, end-of-program, online evaluation. The evaluation form had both year-to-year formative evaluation questions designed for soliciting feedback in order to improve future institutes and summative-evaluation questions to measure the effectiveness of MSRI-UP in accomplishing the program objectives. The quantitative results of the end-of-program evaluation are provided in Appendix A.

Post-program conversations between the MSRI-UP staff and the Directors indicated that the staff felt that the institute was successful in accomplishing its objectives.

15. Post-Summer Conferences

MSRI-UP has a substantial post-summer component. Students are provided funding to attend academic conferences to present their research. In addition, each year the onsite director keeps students informed of conference opportunities and funding sources for attending such conferences.

Indeed, 15 of the program's 17 students, representing all 6 research project teams, presented their research at the 2010 SACNAS National Conference in Anaheim, California, in September-October, 2010. Six students, representing 4 of the research project teams, presented their work at the Joint Mathematics Meetings in New Orleans, Louisiana, in January, 2011. Students have also presented work at their home institutions and regional mathematics conferences.

During the joint meetings at the Mathematical Association of America (MAA) Undergraduate Student Poster Session, 3 of the four MSRI-UP posters that were presented were awarded prizes. The one group that did not win an award at the joint meetings was one of our 3 prize-winning groups at the SACNAS conference three months prior. Between these two prominent national showcases of undergraduate mathematics research, 5 of the MSRI-UP's 6 project teams were honored with prizes.

16. Evidence Already Pointing to Long-Term Success of Program

From the 2007 MSRI-UP, 8 of the 12 undergraduates are currently enrolled in graduate programs. Two of these 2007 program alumni, Gina Pomann and Talea Mayo, received the prestigious and highly competitive NSF Graduate Research Fellowship Awards in 2010.

From the 2008 program, 13 students are currently in graduate programs of the 14 who have finished college.

Six of the nine 2009 students who graduated last year are in doctoral programs, five of those in the mathematical sciences.

17. Conclusion

Like the three summers that preceded it, reviews of the MSRI-UP from its students, staff, and guests have been overwhelming positive. The program is certainly perceived as an overall success, though the real fruit—that of achieving the program's primary goal *to increase the number of graduate degrees in the mathematical sciences, especially doctorates, earned by U.S. citizens and permanent residents by cultivating heretofore untapped mathematical talent*—will take years to realize.

The long-term data that will confirm that the MSRI-UP objectives contribute towards the goal of increasing the number of Latinos/Chicanos, African-American and Native Americans earning graduate degrees in the mathematical sciences will not be available for several years. The Directors are committed to maintain the relationships developed with each cohort of students in the program in order to monitor and collect data on the MSRI-UP students' academic progress and, whenever possible, to provide them with additional academic opportunities.

2010 Mathematical Sciences Research Institute Undergraduate Program (MSRI-UP)
End-of-Program Student Evaluation

Instructions: Glance at the entire evaluation before you start filling it out. Please take sufficient time to fill it out. If you run out of space in a *Comments* section, use the last page. There are a couple of questions that should be filled out after your presentation; these will only take a few minutes. Your input is greatly appreciated. Thank you.

I. Pre-Research Seminar *(First 2 Weeks of MSRI-UP)*

1. Did you find the material, techniques and applications that you learned in the pre-research seminar interesting?
3 ☐ Yes, very interesting. 11 ☐ Yes, interesting. 3 ☐ Somewhat interesting. 0 ☐ No.
Comments:

2. Was the seminar time used effectively?
6 ☐ Yes, very effectively. 9 ☐ Yes, effectively. 2 ☐ Somewhat effectively. 0 ☐ No.
Comments:

3. On a scale of 1-5 please rate the usefulness of each of the following in helping you to learn the material presented in the pre-research seminar. X = does not apply, 1=not useful, 5 = very useful.

	X	1	2	3	4	5	
A	0	0	0	5	5	7	Lectures
B	0	0	2	4	5	6	Homework assignments
C	0	0	0	1	4	12	Notes written by Prof. Goins
D	1	0	1	2	2	11	Interaction and collaboration with seminar mates
E	1	3	1	5	4	3	One-on-one or group sessions with research leader, postdoc or TAs

Comments:

4. What other activities helped or would have helped you to learn the mathematics needed for your research?

5. The pace at which new material was presented was:
7 ☐ Too fast. 10 ☐ Just right. 0 ☐ Too slow.
Comments:

6. The amount of homework during the first week was:
12 ☐ About the correct amount to help you learn the material. 4 ☐ Too much. 0 ☐ Too little.
Comments:

7. The help, support, feedback and encouragement from the professor, postdoc, GAs and other staff was:
8 ☐ The correct amount. 5 ☐ Just below the correct amount. 4 ☐ Not enough. 0 ☐ None.
Comments:

8. Please comment on any other pre-research aspect of MSRI-UP. (e.g., if you could change anything about the pre-research phase, what would you change?)

II. Research Projects

1. Your research project was:
   11 ☐ Clearly-defined. 3 ☐ Not clearly-defined. 0 ☐ Not defined at all.
   Comments:

2. The mathematical level of your research project was:
   0 ☐ Way too challenging. 14 ☐ Challenging. 2 ☐ Not very challenging 0 ☐ Too easy.
   Comments:

3. The guidance and support on your project that you received from the research mentor and associates was:
   3 ☐ The correct amount. 8 ☐ Just below the correct amount. 5 ☐ Not enough. 0 ☐ None.
   Comments:

4. Comment on the adequacy (or lack thereof) of the computing facilities for carrying out the work on your project.

5. Comment on the adequacy (or lack thereof) of reference material available for carrying out the work on your project.

6. Did you like working on a group research project?
   4 ☐ Yes, very much. 10 ☐ Yes. 3 ☐ A little. 0 ☐ No.
   Comments:

7. The guidance on preparing your oral presentation, poster, and technical report was:
   7 ☐ The correct amount. 7 ☐ Just below the correct amount. 2 ☐ Not enough. 0 ☐ None.
   Comments:

8. How satisfied with the results of your research project are you?
   1 ☐ Very satisfied. 13 ☐ Satisfied. 3 ☐ Not satisfied.
   Comments:

9. How satisfied are you with the quality of your
   A. Oral presentation? 7 ☐ Very satisfied. 7 ☐ Satisfied. 3 ☐ Not satisfied.
   Comments:

   B. Technical report? 4☐ Very satisfied. 11½☐ Satisfied. 1½☐ Not satisfied.
   Comments:

C. Poster? 2 ☐ Very satisfied. 14½ ☐ Satisfied. ½ ☐ Not satisfied.
Comments:

10. What did you like most about your research project?

11. What did you dislike most about your research project?

12. Please comment on any other aspect of the research part of MSRI-UP. (e.g., if you could change anything about your research experience, what would you change?)

13. Only answer this question if you have participated in other undergraduate research projects or summer programs. How does your research experience during MSRI-UP compare with your other research experiences?

III. Workshops, Colloquia, Other Academics not Evaluated Above

2010 Colloquium Speakers: Herbert Medina, Alejandra Alvarado, Stephanie Somersille, Suzanne Weekes, Emille Davie

1. Do you feel that the colloquia were successful giving you a glimpse of other areas of mathematics?
   5 ☐ Yes, very much so. 10 ☐ Yes, somewhat. 0 ☐ Not really. 0 ☐ Not at all.

2. Do you feel that the colloquia allowed you to meet researchers and faculty at universities with graduate programs?
   6 ☐ Yes, very much so. 7 ☐ Yes, somewhat. 2 ☐ Not really. 0 ☐ Not at all.

3. Which was your favorite colloquium? Least favorite?
   Favorite: ________________________ *Least Favorite*: ________________________

4. On a scale of 0-4 please rate the usefulness of each of the following Friday am sessions. 0 = not useful, 4 = very useful.

0	**1**	**2**	**3**	**4**	**Workshop or panel**
0	2	1½	5½	8	LaTeX and Beamer workshop
0	0	1	4	12	Graduate and fellowship workshop
0	1	3½	8 ½	4	Graduate student panel discussion
3	1	8	4	1	Presentations Workshop: Poster, Oral, Written (POW!)

Comments:

5. Is there a workshop, discussion or panel topic that you would have liked? Please describe.

IV. Measuring Some MSRI-UP Objectives

1. Prior to MSRI-UP, had you worked on an undergraduate research project in mathematics? 10 ☐ Yes. 7 ☐ No.
   Comments:

2. After MSRI-UP, do you want work on an undergraduate research project in mathematics? 16 ☐ Yes. 1 ☐ No.
   Comments:

3. Presently, I am
   0 ☐ not 1 ☐ a little 6 ☐ somewhat 7 ☐ highly 3 ☐ extremely
   confident I can understand what research in mathematics is about.
   Comments:

4. Presently, I am
   0 ☐ not 1 ☐ a little 2 ☐ somewhat 7 ☐ highly 7 ☐ extremely
   confident I can understand what are the advantages of an undergraduate research experience.
   Comments:

5. Presently, I am
   0 ☐ not 1 ☐ a little 6 ☐ somewhat 6 ☐ highly 4 ☐ extremely
   confident I can understand what are the job opportunities for mathematics majors.
   Comments:

6. Presently, I am
   0 ☐ not 0 ☐ a little 4 ☐ somewhat 9 ☐ highly 4 ☐ extremely
   confident I can understand what are the fellowships and graduate study opportunities in mathematics.
   Comments:

7. Presently, I am
   0 ☐ not 1 ☐ a little 5½ ☐ somewhat 10½ ☐ highly 0 ☐ extremely
   confident I can write a technical article.
   Comments:

8. Presently, I am
   0 ☐ not 3 ☐ a little 9 ☐ somewhat 9 ☐ highly 2 ☐ extremely
   confident I can design a scientific poster
   Comments:

9. Presently, I am

0 ☐ not 1 ☐ a little 2 ☐ somewhat 9 ☐ highly 5 ☐ extremely

confident I can give an oral presentation.

Comments:

10. Presently, I am

0 ☐ not 3 ☐ a little 5 ☐ somewhat 8 ☐ highly 1 ☐ extremely

confident I can find data or articles in journals or elsewhere

Comments:

11. Presently, I am

0 ☐ not 1 ☐ a little 5 ☐ somewhat 8 ☐ highly 3 ☐ extremely

confident I can use a software like Mathematica, Maple, or Sage to program or solve some mathematics problems.

Comments:

12. Presently, I am

0 ☐ not at all 1 ☐ a little 4 ☐ somewhat 5 ☐ highly 7 ☐ extremely

interested in discussing about mathematics with friends or family.

Comments:

13. Presently, I am

1 ☐ not at all 1 ☐ a little 4 ☐ somewhat 8 ☐ highly 3 ☐ extremely

interested in reading articles about mathematics in magazines, journals or the internet.

Comments:

14. Presently, I am

0 ☐ not at all 1 ☐ a little 1 ☐ somewhat 4 ☐ highly 11 ☐ extremely

interested in taking additional courses in mathematics.

Comments:

15. Presently, I am

0 ☐ not at all 1 ☐ a little 1 ☐ somewhat 4 ☐ highly 11 ☐ extremely

interested in attending graduate school in mathematics.

Comments:

16. Presently, I am

0 ☐ not at all 2 ☐ a little 1 ☐ somewhat 7 ☐ highly 7 ☐ extremely

interested in having another undergraduate research experience.

Comments:

V. Non-Academic Aspects of MSRI-UP and General Questions

1. On a scale of 0-4 please rate how happy were you with each of the following.
   0 = not happy at all, 4 = very happy.

	0	1	2	3	4	
A	1	1	2	8½	4½	Living arrangements.
B	½	2½	3	8	3	Eating arrangements.
C	0	0	½	2	14½	Saturday outings.
D	0	0	1	3	13	Number of students in the program.
E	0	0	1	4	12	Transportation arrangements.
F	0	0	½	5½	11	Overall design, organization and administration of the program.

Comments (Use back of page if necessary):

2010 Excursions: (1) San Francisco-Cable Car-Alcatraz, (2) Kayaking, (3) Santa Cruz Beach Boardwalk, (4) Baseball Game and Fireworks, (5) Mount Tamalpais-Sausalito-Golden Gate Bridge.

2. Which was your favorite outing? Why?

3. Which was your least favorite outing? Why?

4. What are the things that you particularly liked about the program?

5. What are the things that you particularly disliked about the program?

6. Do you think that MSRI-UP has changed your outlook on your academic future? If so, how?

7. Please use the back to add any additional comments that you think are important or relevant to any aspect of MSRI-UP.

8. What is your gender?
8 ☐ female 9 ☐ male.

11. Has anyone in your family attended graduate school?
5 ☐ yes 11 ☐ no.

12. Have you attended mathematics or science meetings in the past?
9 ☐ yes 7 ☐ no.

13. Have you presented at a national meetings in the past?
5 ☐ yes 11 ☐ no.

VI. Dr. Cooper's Pet Questions

1. ***Mathematically***, what was the most valuable or memorable experience or incident during MSRI-UP to you?

2. ***Otherwise***, what was the most valuable or memorable experience or incident during MSRI-UP to you?

3. List things you wish you had known *before you arrived* on June 12 regarding any aspects of the program.

4. What advice would you give to a friend *applying* to the 2011 MSRI-UP and to a friend *accepted* to the program?

MSRI-UP 2010 Calendar, Weeks 1 and 2 (Actual)

	Sunday 13-June	Monday 14-June	Tuesday 15-June	Wednesday 16-June	Thursday 17-June	Friday 18-June	Saturday 19-June
8:10 AM		8:40, "Hill Line" Shuttle	8:10, 8:40, 9:10,	8:10, 8:40, 9:10,	8:10, 8:40, 9:10,	8:10, 8:40, 9:10,	
9:00 AM		9, ID badges, keys, etc.	Shuttle to MSRI	Shuttle to MSRI	Shuttle to MSRI	Shuttle to MSRI	
9:30 AM		9:30 Welcome to MSRI	9:30-12, Lecture	9:30-12, Lecture	9:30-12, Lecture	9:30-12, LaTeX Workshop	
10:00 AM		9:50-12, Lecture					10:00 - ?
11:00 AM							
Noon		Lunch	Lunch	Lunch	Lunch	Lunch	San
1:00 PM		1, 1:30, 2: Library tours,					Francisco
1:30 PM		Paperwork, Small	1:30-3:30, Problem	1:30-3:30, Problem	1:30-3:30, Problem		
2:00 PM		group meetings	Solving/Lect./Tutorial	Solving/Lect./Tutorial	Solving/Lect./Tutorial	2-3:30, Colloquium,	
3:00 PM		2:30-5: Problem				Herbert Medina	
3:30 PM		Solving/Lect./Tutorial	3:30, Tea	3:30, Tea	3:30, Tea	3:30, Tea	
4:00 PM			4-5, Stdt. presentations	4-5, Stdt. presentations	4-5, Stdt. presentations	Shuttle to Mining Circle	
5:00 PM	MSRI-UP	Shuttle to Mining Circle	Shuttle to Mining Circle	Shuttle to Mining Circle	Shuttle to Mining Circle	3:55, 4:25, 4:55,	
5:30 PM	Orientation	5:25, 5:55, 6:25	5:25, 5:55, 6:25	5:25, 5:55, 6:25	5:25, 5:55, 6:25	5:25, 5:55, 6:25	

	Sunday 20-June	Monday 21-June	Tuesday 22-June	Wednesday 23-June	Thursday 24-June	Friday 25-June	Saturday 26-June
8:10 AM		8:10, 8:40, 9:10,	8:10, 8:40, 9:10,	8:10, 8:40, Shuttle	8:10, 8:40, 9:10,	8:10, 8:40, 9:10,	
9:00 AM		Shuttle to MSRI	Shuttle to MSRI	9-11:15, Lecture	Shuttle to MSRI	Shuttle to MSRI	
9:30 AM		9:30-12, Lecture	9:30-12, Lecture		9:30-12, Lecture	9:30-12, Graduate School	
10:00 AM						and Fellowship	
11:00 AM				11:30 Begin hike for		Workshop	11:00 - ?
Noon		Lunch	Lunch	12: MSRI Barbecue	Lunch	Lunch	
1:00 PM							Kayaking
1:30 PM		1:30-3:30, Problem	1:30-3:30, Problem		1:30-3:30, Problem		
2:00 PM		Solving/Lect./Tutorial	Solving/Lect./Tutorial		Solving/Lect./Tutorial	2-3:30, Colloquium,	
3:00 PM				3-5, Problem		Alejandra Alvarado	
3:30 PM		3:30, Tea	3:30, Tea	Solving/Lect./Tutorial	3:30, Tea	3:30, Tea	
4:00 PM		4-5, Stdt. presentations	4-5, Stdt. presentations		4-5, Stdt. presentations	Shuttle to Mining Circle	
5:00 PM		Shuttle to Mining Circle	Shuttle to Mining Circle	Shuttle to Mining Circle	Shuttle to Mining Circle	3:55, 4:25, 4:55,	
5:30 PM		5:25, 5:55, 6:25	5:25, 5:55, 6:25	5:25, 5:55, 6:25	5:25, 5:55, 6:25	5:25, 5:55, 6:25	

MSRI-UP 2010 Calendar, Weeks 3 and 4

	Sunday 27-June	Monday 28-June	Tuesday 29-June	Wednesday 30-June	Thursday 1-July	Friday 2-July	Saturday 3-July
8:10 AM		8:10, 8:40, 9:10,	8:10, 8:40, 9:10,	8:10, 8:40, Shuttle	8:10, 8:40, 9:10,	8:10, 8:40, 9:10,	
9:00 AM		Shuttle to MSRI	Shuttle to MSRI	9-11:15, Research	Shuttle to MSRI	Shuttle to MSRI	
9:30 AM		9:30-11:45, Student	9:30-11:45, Research	Team Meetings	9:30-11:45, Research	9:30-10:15, Conf. Prep.	9:30 - 9:30
10:00 AM		presentations	Team Meetings		Team Meetings	10:30-12, Graduate	
11:00 AM				11:30-12:20,		Student Panel	Santa
Noon		Lunch	Lunch	Colloquium, Ken Ribet	Lunch	Lunch	Cruz
1:00 PM				Lunch			Beach
1:30 PM		1:15-3:30, Research	1:15-3:30, Research	1:15-3:30, Research	1:15-3:30, Research		Boardwalk
2:00 PM		Team Meetings	Team Meetings	Team Meetings	Team Meetings	2-3:30, Colloquium,	
3:00 PM						Stephanie Somersille	
3:30 PM		3:30, Tea	3:30, Tea	3:30, Tea	3:30, Tea	3:30, Tea	
4:00 PM		4-5:15, Research Teams	4-5:15, Research Teams	4-5:15, Research Teams	4-5:15, Research Teams	Shuttle to Mining Circle	
5:00 PM		Shuttle to Mining Circle	Shuttle to Mining Circle	Shuttle to Mining Circle	Shuttle to Mining Circle	3:55, 4:25, 4:55,	
5:30 PM		5:25, 5:55, 6:25	5:25, 5:55, 6:25	5:25, 5:55, 6:25	5:25, 5:55, 6:25	5:25, 5:55, 6:25	

	Sunday	Monday 5-July	Tuesday 6-July	Wednesday 7-July	Thursday 8-July	Friday 9-July	Saturday 10-July
8:10 AM	4-July		8:10, 8:40, 9:10,	8:10, 8:40, 9:10,	8:10, 8:40, 9:10,	8:10, 8:40, 9:10,	
9:00 AM			Shuttle to MSRI	Shuttle to MSRI	Shuttle to MSRI	Shuttle to MSRI	
9:30 AM			9:30-11:45, Research	9:30-11:45, Research	9:30-11:45, Research	9:30-11:45, Research	
10:00 AM		Federal, Campus,	Team Meetings	Team Meetings	Team Meetings	Team Meetings	
11:00 AM		and MSRI-UP Holiday					
Noon			Lunch	Lunch	Lunch	Lunch	
1:00 PM	Volleyball						
1:30 PM	Challenge,		1:15-3:30, Research	1:15-3:30, Research	1:15-3:30, Research		4:00 - ?
2:00 PM	RSF		Team Meetings	Team Meetings	Team Meetings	2-3:30, Colloquium,	
3:00 PM						Suzanne Weekes	MLBaseball:
3:30 PM		3:30, Nap	3:30, Tea	3:30, Tea	3:30, Tea	3:30, Tea	Oakland A's
4:00 PM	Ind. Day on		4-5:15, Research Teams	4-5:15, Research Teams	4-5:15, Research Teams	Shuttle to Mining Circle	vs.
5:00 PM	your own		Shuttle to Mining Circle	Shuttle to Mining Circle	Shuttle to Mining Circle	3:55, 4:25, 4:55,	L.A. Angels
5:30 PM			5:25, 5:55, 6:25	5:25, 5:55, 6:25	5:25, 5:55, 6:25	5:25, 5:55, 6:25	& fireworks

MSRI-UP 2010 Calendar, Weeks 5 and 6 (Actual)

	Sunday 11-July	Monday 12-July	Tuesday 13-July	Wednesday 14-July	Thursday 15-July	Friday 16-July	Saturday 17-July
8:10 AM		8:10, 8:40, 9:10,	8:10, 8:40, 9:10,	8:10, 8:40, Shuttle	8:10, 8:40, 9:10,	8:10, 8:40, 9:10,	
9:00 AM		Shuttle to MSRI	Shuttle to MSRI	9-11:15, Research	Shuttle to MSRI	Shuttle to MSRI	
9:30 AM		9:30-11:45, Student	9:30-11:45, Research	Team Meetings	9:30-11:45, Research	9:30-12, Presentations	
10:00 AM		presentations	Team Meetings		Team Meetings	Workshop: Poster,	10-6,
11:00 AM				11:25, Shuttle to UC		Oral, Written (POW!)	
Noon		Lunch	Lunch	Lunch at Fac. Club with	Lunch	Lunch	Marin Co.:
1:00 PM				Berkeley Edge Prog.			Mount
1:30 PM		1:15-3:30, Research	1:15-3:30, Research	1:40, Shuttle to MSRI	1:15-3:30, Research		Tamalpais,
2:00 PM		Team Meetings	Team Meetings	2-3:30, Research	Team Meetings	2-3:30, Colloquium,	Sausalito,
3:00 PM				Team Meetings		Emille Davie	and the
3:30 PM		3:30, Tea	3:30, Tea	3:30, Tea	3:30, Tea	3:30, Tea	Golden
4:00 PM		4-5:15, Research Teams	4-5:15, Research Teams	4-5:15, Research Teams	4-5:15, Research Teams	Shuttle to Mining Circle	Gate Bridge
5:00 PM		Shuttle to Mining Circle	Shuttle to Mining Circle	Shuttle to Mining Circle	Shuttle to Mining Circle	3:55, 4:25, 4:55,	
5:30 PM		5:25, 5:55, 6:25	5:25, 5:55, 6:25	5:25, 5:55, 6:25	5:25, 5:55, 6:25	5:25, 5:55, 6:25	

	Sunday 18-July	Monday 19-July	Tuesday 20-July	Wednesday 21-July	Thursday 22-July	Friday 23-July	Saturday 24-July
8:10 AM		8:10, 8:40, 9:10,	8:10, 8:40, 9:10,	8:10, 8:40, 9:10,	8:10, 8:40, 9:10,	8:10, 8:40, 9:10,	
9:00 AM		Shuttle to MSRI	Shuttle to MSRI	Shuttle to MSRI	Shuttle to MSRI	Shuttle to MSRI	
9:30 AM		9:30-11:45, Student	9:30-11:45, Research	9:30-11:45, Research	9:30-11:45, Research	9:30, 10:15, 11,	
10:00 AM		presentations	Team Meetings	Team Meetings	Team Meetings	Final Research	
11:00 AM						Presentations	
Noon		Lunch	Lunch	Lunch	Lunch	Lunch	
1:00 PM				12:30, Hyena Colony			
1:30 PM		1:15-3:30, Research	1:15-3:30, Research	visit (optional)	1:15-3:30, Research	1:15, 2, 2:45,	
2:00 PM		Team Meetings	Team Meetings	1:45-3:30, Research	Team Meetings	Final Research	
3:00 PM				Team Meetings		Presentations	
3:30 PM		3:30, Tea	3:30, Tea	3:30, Tea	3:30, Tea	3:30, Tea	
4:00 PM		4-5:15, Research Teams	4-5:15, Research Teams	4-5:15, Research Teams	4-5:15, Research Teams	Shuttle to Mining Circle	6-9,
5:00 PM		Shuttle to Mining Circle	Shuttle to Mining Circle	Shuttle to Mining Circle	Shuttle to Mining Circle	3:55, 4:25, 4:55,	Farewell
5:30 PM		5:25, 5:55, 6:25	5:25, 5:55, 6:25	5:25, 5:55, 6:25	5:25, 5:55, 6:25	5:25, 5:55, 6:25	Dinner

Rational Distance Sets on Conic Sections

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Abstract

Leonard Euler noted that there exists an infinite set of rational points on the unit circle such that the pairwise distance of any two is also rational. Given any conic section, we find a necessary and sufficient condition for there to exist a rational distance set of at least five points. We apply elliptic curves to generate a method for finding rational distance sets.

1 Introduction

A rational distance set is a set whose elements have pairwise rational distance. Finding these sets is a difficult problem and even more difficult is the search for rational distance sets with rational coordinates.

The search for rational distance sets has a long history. Leonard Euler noted that there exists an infinite set of rational points on the unit circle such that the pairwise distance of any two is also rational.

In 1945 Stanislaw Ulam posed a question about a rational distance set: is there an everywhere dense rational distance set in the plane[3]? Paul Erdos also considered the problem and he conjectured that the only irreducible algebraic curves which have an infinite rational distance set are the line and the circle[2]. This was later proven to be true by Jozsef Solymosi and Frank de Zeeuw[2].

First, we provide the formal definition of a rational distance set:

Definition 1. A **rational distance set** S is a set of elements $P_i = (x_i, y_i) \in \mathbb{R}^2$, $1 \leq i \leq n, n \in \mathbb{Z}$, such that for all $P_i, P_j \in S, i \neq j$, $||P_i - P_j||$ is a rational number.

We are primarily concerned with finding rational distance sets of rational points. The distance between two points on a graph is $\sqrt{(x_i - x_j)^2 + (y_i - y_j)^2}$. It will prove useful to rewrite this formula as

$$|x_i - x_j| \sqrt{1 + (\frac{y_i - y_j}{x_i - x_j})^2} \tag{1}$$

Now, consider the following lemma:

Lemma 1. *The rational solutions to the equation*

$$\alpha^2 = 1 + \beta^2 \tag{2}$$

can be parametrized by $\alpha = \frac{m^2+1}{2m}, \quad \beta = \frac{m^2-1}{2m}$*, for* $m \in \mathbb{Q}, m \neq 0$.

For the proof, refer to Campbell's paper [1].

2 Main results

2.1 Line

Theorem 1. *For any line $L : ax + by + c = 0$, for $a, b, c \in \mathbb{Q}$ and $a \neq 0$ or $b \neq 0$, there exists a dense rational distance set with rational coordinates if and only if there exists $m \in \mathbb{Q}$ such that $a^2 + b^2 = m^2$.*

Proof. Suppose L has a dense rational distance set with rational coordinates. Let $b \neq 0$, though we could equivalently let $a \neq 0$, as the presiding condition is that a and b are not simultaneously zero. Then we can express the line L as $y = -\frac{a}{b}x - \frac{c}{b}$. Consider two points on L, (x_i, y_i) and (x_j, y_j). We can write the distance between these two points as

$$|x_i - x_j| \sqrt{1 + \left(\frac{a}{b}\right)^2} \tag{3}$$

using Lemma 1.

The distance is rational only if $1 + \frac{a^2}{b^2} = n^2$ for $n \in \mathbb{Q}$. That is, if $a^2 + b^2 = n^2 b^2$. Hence, we get $m = bn$.

Suppose $a^2 + b^2 = m^2$ for $m \in \mathbb{Q}$. Let $b \neq 0$,then line L can be written as $y = -\frac{a}{b}x - \frac{c}{b}$. The distance between two rational points on L, (x_i, y_i) and (x_j, y_j), is $|x_i - x_j| \sqrt{1 + \left(\frac{a}{b}\right)^2}$, from Lemma 1. Note that we can write $a^2 + b^2 = m^2$ as $1 + \frac{a^2}{b^2} = \frac{m^2}{b^2}$. Hence we see $\sqrt{1 + \frac{a^2}{b^2}} = \frac{m}{b}$, which is rational. □

2.2 Circle

Theorem 2. *Let $r \in \mathbb{Q}$ with $r \neq 0$. Given a circle C: $\|z - z_0\| = r$ in the complex plane and a vertical line L:* $\mathrm{Re}\, z = \frac{1}{2r}$. *Let f be the following Möbius transformation*

$$f\colon \mathbb{P}^1(\mathbb{C}) \to \mathbb{P}^1(\mathbb{C}) \text{ defined by } f(z) = \frac{(z_0 - r)z + 1}{z},$$

that maps the line L into the circle C. Therefore for any circle C there exists a rational distance set.

Proof. Consider the transformation $f(z) = \frac{(z_0-r)z+1}{z}$.

Since f is a Möbius transformation, f preserves the map from lines to circles. Therefore we can choose 3 points on the line, determine where f maps them, and then determine the unique circle that passes through those three points. Picking $\frac{1}{2r}, \frac{1}{2r} - i\frac{1}{2r}, \frac{1}{2r} + i\frac{1}{2r}$, we get $f(\frac{1}{2r}) = z_0 + r$, $f(\frac{1}{2r} - i\frac{1}{2r}) = z_0 - ir$, $f(\frac{1}{2r} + i\frac{1}{2r}) = z_0 + ir$. These are three points on the circle $\|z - z_0\| = r$.

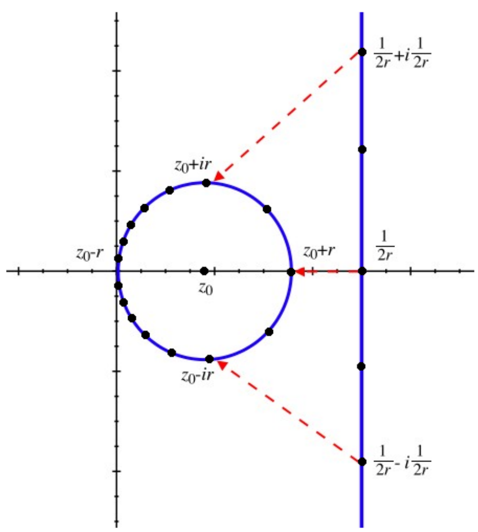


Figure 1: Example of a line that maps to a circle.

For example, for a circle with radius $r < 1$ centered at z_0 there exists a bijection between the circle and the line as shown in figure 1. The rationality of the distance between the points on the the codomain follows from the identity

$$\left\| \frac{1}{z} - \frac{1}{w} \right\| = \frac{\|z - w\|}{\|z\| \cdot \|w\|}.$$

$\square$

2.3 Finding Rational Distance Sets on a Parabola

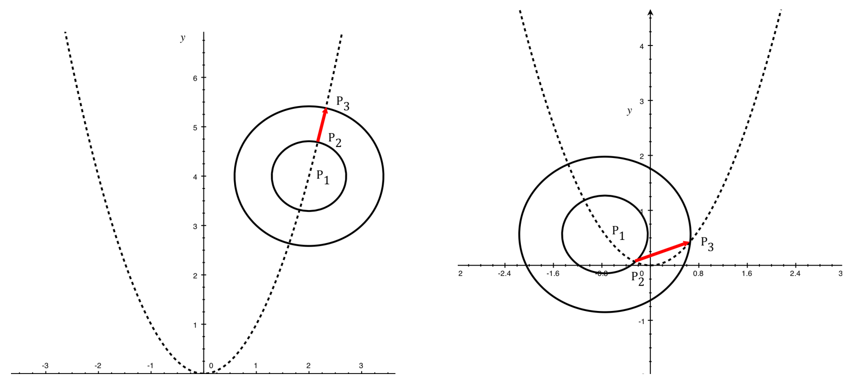
Consider the parabola $y = ax^2 + bx + c$ where $a, b, c, \in \mathbb{Q}$.

We provide a geometric intuition of the problem. One major note for this construction is that the points are at rational distance, but they do not have to be rational. We present a method for constructing a rational distance set of three points on a parabola: First, we choose some point on the parabola and construct a circle of rational radius around it. We then construct a second concentric circle of rational radius, as shown in figure 2.

In figure 2, we see that the line segments P_1P_2 and P_1P_3 are rational. All we require now is that P_2P_3 be rational. This segment is not necessarily rational. We can, however, make it rational. If we allow the contruction to move along the parabola, we notice that the length of segment P_2P_3 changes. We see from this construction that the length of segment P_2P_3 is a continuous function on an interval. Therefore, we can find some point in the parabola such that the segment P_2P_3 is rational.

First, we will introduce minor results for clarification.

By equation 1, the distance d_{ij} between two rational points P_i and P_j on a



(a) The parabola and two concentric circles with their center on the parabola.

(b) The construction in Figure 2(a) has been moved along the parabola, to the left.

Figure 2: The Line Segment P_2P_3 at Two Different Points

parabola is

$$d_{ij} = |x_i - x_j| \sqrt{1 + (ax_i + ax_j + b)^2}.$$

By Lemma 1, $ax_i + ax_j + b = \frac{m^2-1}{2m}$. We let $g(m) = \frac{1}{a}(\frac{m^2-1}{2m} - b)$, which gives the following theorem:

Theorem 3. *Given a parabola $y = ax^2 + bx + c$, let $S = \{P_1, P_2, P_3\}$. S is a rational distance set of rational points if and only if $1 \leq i < j \leq 3$ we can find a nonzero rational value m_{ij} such that*

$$\begin{aligned} x_1 &= \frac{g(m_{12}) + g(m_{13}) - g(m_{23})}{2} \\ x_2 &= \frac{g(m_{12}) - g(m_{13}) + g(m_{23})}{2} \\ x_3 &= \frac{-g(m_{12}) + g(m_{13}) + g(m_{23})}{2} \end{aligned}$$

Proof. For each $1 \leq i < j \leq 3$ where $x_i + x_j = g(m_{ij})$, we have three equations:

$$\begin{aligned} x_1 + x_2 &= g(m_{12}) \\ x_1 + x_3 &= g(m_{13}) \\ x_2 + x_3 &= g(m_{23}) \end{aligned}$$

This is equivalent to the following row reduced augmented matrix:

$$\begin{pmatrix} 1 & 0 & 0 & \frac{g(m_{12})+g(m_{13})-g(m_{23})}{2} \\ 0 & 1 & 0 & \frac{g(m_{12})-g(m_{13})+g(m_{23})}{2} \\ 0 & 0 & 1 & \frac{-g(m_{12})+g(m_{13})+g(m_{23})}{2} \end{pmatrix}$$

which gives us our desired values.

$\square$

We can follow a similar argument to find a rational distance set of four rational points on a parabola.

Theorem 4. *Given a parabola $y = ax^2 + bx + c$, let $T = \{P_1, P_2, P_3, P_4\}$. T is a rational distance set of rational points if and only if there are rational values m_{ij}, $1 \leq i < j \leq 4$ such that*

$$\begin{aligned} x_1 &= \frac{1}{2}(g(m_{12}) + g(m_{13}) - g(m_{23})) \\ x_2 &= \frac{1}{2}(g(m_{12}) - g(m_{13}) + g(m_{23})) \\ x_3 &= \frac{1}{2}(-g(m_{12}) + g(m_{13}) + g(m_{23})) \\ x_4 &= \frac{1}{2}(-g(m_{12}) - g(m_{13}) + g(m_{23}) + 2g(m_{14})) \end{aligned}$$

and $g(m_{13}) + g(m_{24}) = g(m_{23}) + g(m_{14}) = g(m_{12}) + g(m_{34})$

Proof. For each $1 \leq i < j \leq 4$ where $x_i + x_j = g(m_{ij})$, we have six equations:

$$\begin{aligned} x_1 + x_2 &= g(m_{12}) \\ x_1 + x_3 &= g(m_{13}) \\ x_1 + x_4 &= g(m_{14}) \\ x_2 + x_3 &= g(m_{23}) \\ x_2 + x_4 &= g(m_{24}) \\ x_3 + x_4 &= g(m_{34}) \end{aligned}$$

This is equivalent to the following row reduced augmented matrix:

$$\begin{pmatrix} 1 & 0 & 0 & 0 & \frac{g(m_{12})+g(m_{13})-g(m_{23})}{2} \\ 0 & 1 & 0 & 0 & \frac{g(m_{12})-g(m_{13})+g(m_{23})}{2} \\ 0 & 0 & 1 & 0 & \frac{-g(m_{12})+g(m_{13})+g(m_{23})}{2} \\ 0 & 0 & 0 & 1 & \frac{-g(m_{12})-g(m_{13})+g(m_{23})+2g(m_{14})}{2} \\ 0 & 0 & 0 & 0 & g(m_{13})+g(m_{24})-g(m_{23})-g(m_{14}) \\ 0 & 0 & 0 & 0 & g(m_{12})+g(m_{34})-g(m_{23})-g(m_{14}) \end{pmatrix}$$

which gives us our desired equations. □

Definition 2. A set of points is **concyclic** if they lie on a common circle. Similarly, a set of points is **nonconcyclic** if one cannot construct a common circle through them.

We will now examine the cases of concyclic and nonconcyclic points on a parabola.

2.4 Concyclic Points on a Parabola

Proposition 1. *If P_i for $1 \leq i \leq 4$ are four rational points on the parabola, then they are concyclic if and only if $x_1 + x_2 + x_3 + x_4 = -\frac{2b}{a}$.*

Proof. Let $C_{\alpha,\beta,\rho}$ be the circle $(x-\alpha)^2 + (y-\beta)^2 = \rho^2$, where $\alpha, \beta, \rho \in \mathbb{R}$. This circle intersects $y = ax^2 + bx + c$ at the points whose x-coordinates are the roots $(x-\alpha)^2 + (ax^2 + bx + c - \beta)^2 - \rho^2$ or $a^2x^4 + 2abx^3 + (2a(c-\beta) + b^2 + 1)x^2 + 2b(c-\beta)x + (c-\beta)^2$. Since the coefficient of x^3 is $\frac{2b}{a}$, $-(x_1 + x_2 + x_3 + x_4) = \frac{2b}{a}$.

Now if we have x_i, $1 \leq i \leq 4$ such that $-(x_1 + x_2 + x_3 + x_4) = \frac{2b}{a}$, then we must have the following:

$$a^2(x-x_1)(x-x_2)(x-x_3)(x-x_4) = a^2x^4 + 2abx^3 + (2a(c-\beta) + b^2 + 1)x^2 + 2b(c-\beta)x + (c-\beta)^2.$$

So, we see that $x_1 + x_2 + x_3 + x_4 = -\frac{2b}{a}$, for some α, β, and ρ. $\square$

Theorem 5. *Suppose that P_1, P_2, P_3, and P_4 are rational and concyclic. Then, these points are at rational distance if and only if there are nonzero rational values m_{12}, m_{13}, and m_{23} such that the equations of Theorem 4 hold. If we have this condition, then $x_4 = -\frac{1}{2}(g(m_{12}) + g(m_{13}) + g(m_{23}) + \frac{4b}{a})$.*

Proof. By proposition 1, $x_4 = -(x_1 + x_2 + x_3 + \frac{2b}{a})$. Therefore, we can directly solve for x_4 using the values given for the x_1, x_2, x_3. Inputting, our values in, we get $x_4 = -\frac{1}{2}(g(m_{12}) + g(m_{13}) + g(m_{23}) + \frac{4b}{a})$. $\square$

2.5 Non-Concyclic Points on a Parabola

Since the case for nonconcyclic points on a parabola is more difficult, we want to ensure that the rational distance set of four rational points on the parabola is nonconcyclic. We therefore need to examine the last condition of Theorem (4): $g(m_{13}) + g(m_{24}) = g(m_{23}) + g(m_{14}) = g(m_{12}) + g(m_{34})$, in order to find our six m_{ij} values. Consider the surface $g(m_{ij}) + g(m_{kl}) = t$. We can make the following substitutions:

$$m_{ij} = \frac{X^2 + X}{Y - TX}, \quad m_{kl} = \frac{X + 1}{Y - TX}, \quad t = \frac{T - 2b}{a},$$

to obtain the elliptic curve $\mathcal{E} : Y^2 = X^3 + (T^2 + 2)X^2 + X$. Thus if we find rational points on the elliptic curve we can find rational m_{ij} values that satisfy the last condition.

2.6 Example

In order to illustrate this process, we include the following example:

Given the parabola $y = x^2$, let $T = \frac{13}{6}$ in order to get the following elliptic curve $\mathcal{E} : Y^2 = X^3 + \frac{241}{36}X^2 + X$. We chose $T = \frac{13}{6}$ because it is a small rational value that gives us an elliptic curve of positive rank.

We get the rational points $Q_1 = (6\colon 19\colon 18), Q_2 = (3\colon 13\colon 36), Q_3 = (30\colon 169\colon 750)$ on $\mathcal{E}$. Now our m_{ij} have the following values: $m_{12} = 3/10, m_{13} = 1/2, m_{23} = 4/3, m_{14} = 4, m_{24} = 6, m_{34} = 15/2$. Which yields the following rational distance set:

$$\left\{ \left(-\frac{307}{240}, \frac{94249}{57600} \right), \left(-\frac{19}{80}, \frac{361}{6400} \right), \left(\frac{127}{240}, \frac{16129}{57600} \right), \left(\frac{757}{240}, \frac{573049}{57600} \right) \right\}.$$

We can follow a similar argument to find a rational distance set of five rational points on a parabola. Following the method for four points we get ten equations:

$$
\begin{aligned}
x_1 + x_2 &= g(m_{12}) \\
x_1 + x_3 &= g(m_{13}) \\
x_1 + x_4 &= g(m_{14}) \\
x_1 + x_5 &= g(m_{15}) \\
x_2 + x_3 &= g(m_{23}) \\
x_2 + x_4 &= g(m_{24}) \\
x_2 + x_5 &= g(m_{25}) \\
x_3 + x_4 &= g(m_{34}) \\
x_3 + x_5 &= g(m_{35}) \\
x_4 + x_5 &= g(m_{34})
\end{aligned}
$$

This is equivalent to the following row reduced augmented matrix:

$$
\begin{pmatrix}
1 & 0 & 0 & 0 & 0 & \frac{g(m_{12})+g(m_{13})-g(m_{23}}{2} \\
0 & 1 & 0 & 0 & 0 & \frac{g(m_{12})-g(m_{13})+g(m_{23}}{2} \\
0 & 0 & 1 & 0 & 0 & \frac{-g(m_{12})+g(m_{13})+g(m_{23})}{2} \\
0 & 0 & 0 & 1 & 0 & \frac{-g(m_{12})-g(m_{13})+g(m_{23})+2g(m_{14})}{2} \\
0 & 0 & 0 & 0 & 1 & \frac{-g(m_{12})-g(m_{13})+g(m_{23})+2g(m_{15})}{2} \\
0 & 0 & 0 & 0 & 0 & g(m_{13})-g(m_{14})-g(m_{23})+g(m_{24}) \\
0 & 0 & 0 & 0 & 0 & g(m_{13})-g(m_{15})-g(m_{23})+g(m_{25}) \\
0 & 0 & 0 & 0 & 0 & g(m_{12})-g(m_{14})-g(m_{23})+g(m_{34}) \\
0 & 0 & 0 & 0 & 0 & g(m_{12})-g(m_{15})-g(m_{23})+g(m_{35}) \\
0 & 0 & 0 & 0 & 0 & g(m_{12})+g(m_{13})-g(m_{14})-g(m_{15})-g(m_{23})+g(m_{45})
\end{pmatrix}
$$

From this matrix, we get the equations:

$$
\begin{aligned}
x_1 &= \frac{g(m_{12})+g(m_{13})-g(m_{23})}{2} \\
x_2 &= \frac{g(m_{12})-g(m_{13})+g(m_{23})}{2} \\
x_3 &= \frac{-g(m_{12})+g(m_{13})+g(m_{23})}{2} \\
x_4 &= \frac{-g(m_{12})-g(m_{13})+g(m_{23})+2g(m_{14})}{2} \\
x_5 &= \frac{-g(m_{12})-g(m_{13})+g(m_{23})+2g(m_{15})}{2}
\end{aligned}
$$

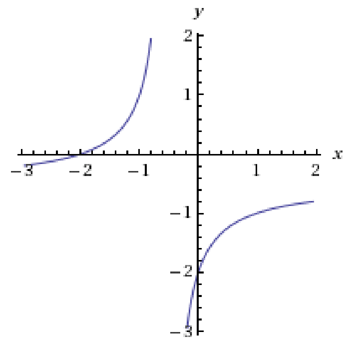


Figure 3: The hyperbola $2xy + x + y + 2 = 0$

2.7 Rational Distance Sets on the Hyperbola

Theorem 6. *Let $a, b, c, d \in \mathbb{Q}$ such that $ad - bc \neq 0$, then there exists a rational distance set of three rational points, $S = \{P_1, P_2, P_3\}$ on the hyperbola $axy + bx + cy + d = 0$.*

Proof. The proof will proceed in several parts. First, we rewrite the distance formula as in equation 1. So, $\frac{y_i - y_j}{x_i - x_j}$ can be paramterized like $\frac{y_i - y_j}{x_i - x_j} = \frac{m_{ij}^2 - 1}{2m_{ij}}$.

Now, we can solve for y_i in our equation for the hyperbola to get the expression: $y_i = -\frac{bx_i + d}{ax_i + c}$. We then substitute y_i into our modified distance formula and this gives the equation $\frac{ad - bc}{(ax_i + c)(ax_j + c)} = \frac{y_i - y_j}{x_i - x_j} = \frac{m_{ij}^2 - 1}{2m_{ij}}$.

Let $D = ad - bc$. If we take $\frac{m^2 - 1}{2m} = Dn^2$ and make the substitutions $m = \frac{X}{2D}$ and $n = \frac{Y}{2DX}$ we get the elliptic curve $\mathcal{E}^{(D)}$: $Y^2 = X^3 - 4D^2X$. We can also obtain the expression $\frac{m^2 - 1}{2m} = Dn^2$ from $\mathcal{E}^{(D)}$ with the substitutions $X = 2Dm$ and $Y = 4D^2mn$.

Now, if we let $Q_i = (X_i : Y_i : 1)$ be rational points on $\mathcal{E}^{(D)}$, then we define the following rational points:

$$n_{23} = \frac{Y_1}{2DX_1},\ n_{13} = \frac{Y_2}{2DX_2},\ n_{12} = \frac{Y_3}{2DX_3}.$$

We define these variables in order to make the following relation hold:

$$\frac{D}{(ax_i+c)(ax_j+c)} = Dn_{ij}^2 = \frac{m_{ij}^2-1}{2m_{ij}}.$$

So, now we define an explicit formula for our rational distance set on the hyperbola:

$$\begin{aligned} P_1 &= \left(\tfrac{n_{23}}{an_{12}n_{13}} - \tfrac{c}{a}, -\tfrac{b}{a} + \tfrac{bcn_{12}n_{13}}{an_{23}}\right) \\ P_2 &= \left(\tfrac{n_{13}}{an_{12}n_{23}} - \tfrac{c}{a}, -\tfrac{b}{a} + \tfrac{bcn_{12}n_{23}}{an_{13}}\right) \\ P_3 &= \left(\tfrac{n_{12}}{an_{13}n_{23}} - \tfrac{c}{a}, -\tfrac{b}{a} + \tfrac{bcn_{13}n_{23}}{an_{12}}\right) \end{aligned}$$

$\square$

In order to illustrate this process, we include the following example:

Given the hyperbola $2xy + x + y + 2 = 0$, we get the following elliptic curve $\mathcal{E}^{(6)}\colon Y^2 = X^3 - 36X$.

We get the rational points $Q_1 = (-3\colon 9\colon 1)\,, Q_2 = (50\colon -35\colon 8)\,, Q_3 = (-58719\colon -321057\colon 50653)$. Now our n_{ij} have the following values: $n_{23} = -\frac{1}{2}, n_{13} = -\frac{7}{60}, n_{12} = \frac{1551}{1709}$. Which yields the following rational distance set:

$$\left\{\left(\frac{40203}{21714}, -\frac{27877}{34040}\right), \left(-\frac{8654}{23265}, -\frac{37876}{5957}\right), \left(\frac{87103}{11914}, -\frac{36977}{62040}\right)\right\}$$

3 Conclusion

4 Acknowledgments

This work was conducted during the 2010 Mathematical Sciences Research Institute Undergraduate Program (MSRI-UP), a program supported by the National Science Foundation (grant No. DMS-0754872) and the National Security Agency (grant No. HB8230-10-1-0233). We also thank Dr. Edray Goins, Dr. Luis Lomelí, Dr. Duane Cooper, Katie Ansaldi, Ebony Harvey, and the MSRI staff.

References

[1] Campbell, Garikai. "'Points on $y = x^2$ at Rational Distance"'. *Mathematics of Computation.*

[2] Solymosi, Jozsef and Frank De Zeeuw. "'On a Question of Erdös and Ulam"'. *Discrete Computational Geometry*

[3] Erdös, Paul. "'Ulam, the Man and the Mathematician"'. *Journal of Graph Theory*

The MSRI summer graduate workshop on Toric Varieties

Organized by

David Cox (Amherst College) and Hal Schenck (University of Illinois at Urbana-Campaign)

Held at MSRI in Berkeley, CA June 15-26

The summer graduate workshop brought together a diverse group of 45 participants, ranging from first through fifth year graduate students, with backgrounds in combinatorics, algebraic and symplectic geometry, and commutative algebra. Toric varieties are a class of algebraic varieties (roughly speaking, objects which look locally like the zeroes of a system of polynomial equations) which lie at the interface of geometry, combinatorics and algebra. The class of toric varieties is both large enough to include a wide range of phenomena and concrete enough to provide an excellent computational environment. This atypical combination leads to applications in many other fields including string theory, coding theory, approximation theory and statistics. Toric varieties also provide a wonderful vehicle for teaching algebraic geometry.

Geometrically, a toric variety is an irreducible algebraic set in which an algebraic torus forms a dense open subset, such that the action of the torus on itself extends to an action on the entire set. Combinatorially, a normal toric variety is determined by a fan; the cones in the fan yield affine varieties and the intersection of cones provide gluing data needed assemble these affine pieces together. Algebraically, an embedded toric variety corresponds to a prime binomial ideal in a polynomial ring. More generally, a toric variety can be described by a multi-graded ring together with an irrelevant ideal. The importance of toric varieties comes from this dictionary between algebraic spaces, discrete geometric objects such as cones and polytopes, and multi-graded commutative algebra.

Because of the wide range of backgrounds, the workshop had a very intense schedule. In the evenings, there were background lectures on basic material in algebraic geometry (ranging, for example, from valuation rings to vector bundles to sheaf cohomology). Each morning, there were two one hour lectures on interpreting algebro-geometric concepts in the toric setting. After lunch, participants were presented with several different sets of problems, ranging from very computational (compute the Picard group of a Hirzebruch surface) to more theoretical (prove a lemma stated during the morning lecture). Participants broke up into small groups of six or seven people, helped when needed by the organizers and two very able TAs (Dustin Cartwright and Daniel Erman) from Berkeley. At the end of the afternoon, the groups presented their results to the whole workshop.

During the latter part of the second week, three guest speakers spoke on topics related to toric geometry: David Eisenbud on the cone of betti tables; Matthias Beck on normality and semigroups; and Sam Payne on toric vector bundles. Participants really enjoyed seeing research talks on topics they had just studied. Among other participant comments:

* The workshop was a truly amazing experience. The only way it to improve it is to make it longer!

* I can't believe how much I learned in these short two weeks.

* Excellent workshop. The problem session/presentation setup was very conducive to working together and understanding the material. Intensive but also fun.

* The format of the workshop, although incredibly intensive, was very effective. Although there was no way for me to have digested everything, I learned a lot. Also, I really enjoyed the problem sessions because it encouraged us to meet each other and socialize.

* The morning lectures gave us the big picture. The afternoon problem sessions filled in the details of the picture; I particularly enjoyed the group work. The evening lectures helped prepare us for the next day's topics. This was an awesome experience.

Lectures from the workshop are available on streaming video at the MSRI website, http://www.msri.org/calendar/sgw/WorkshopInfo/455/show_sgw,
and a draft version of the forthcoming AMS book "Toric Varieties"by Cox, Little and Schenck is available at http://www.cs.amherst.edu/~dac/toric.html

Toric Varieties

Invited Speakers

Cox, David	Amherst College
Schenck, Hal	Texas A&M University
Beck, Matthias	San Francisco State University
Eisenbud, David	UC Berkeley
Payne, Sam	Stanford University
Aragon, Cecilia	UC Berkeley

Participant List

MSRI Workshop:

Toric Varieties

June 15 - 26, 2009

at Mathematical Sciences Research Institute, Berkeley California

Name	Institution
Beaudry, Agnes	Northwestern University
Brannetti, Silvia	Terza Università di Roma
Chan, Melody	University of California
chavez, Anastasia maria	San Francisco State University
Chowdhury, Atoshi	Stanford University
Chung, KiRyong	Seoul National University
Contois, Mark	Washington University
Diemer, Colin	University of Pennsylvania
Dover, James	University of Oklahoma
Duncan, Alex	University of British Columbia
Dutle, Aaron	University of South Carolina
Escobar, Laura	San Francisco State University
Gibbins, Aliska	Ohio State University
Gudmundsson, Hilmar	Reykjavik University
Hardarson, Marteinn	Reykjavik University
Hinkelmann, Franziska	Virginia Polytechnic Institute and State University
Hsiao, Jen-Chieh	Purdue University
Kang, Ning	University of Texas
Kazanova, Anna	University of Massachusetts
Kodgis, Lisa	University of Hawaii
Kositwattanarerk, wittawat	Clemson University
Li, Zhiyuan	Rice University
Lin, Jan-Li	Indiana University
Lin, Kuei-Nuan	Purdue University
Mahmood, Fatima	Cornell University
Malmskog, Elizabeth	Coloroado State University
Mathews, Bryant	University of California
Miller, Jason	Ohio State University
Mondal, Pinaki	University of Toronto
Mukhopadhyay, Swarnava	University of North Carolina
Novoseltsev, Andrey	University of Alberta
O'Keefe, Augustine	Tulane University
Pabiniak, Milena Dorota	Cornell University
Pham, Vinh An	University of Missouri
Ravikumar, Vijay	Rutgers University
Sachitano, David	California State University
Seceleanu, Alexandra	University of Illinois at Urbana-Champaign
Shao, Yijun	University of Arizona
Slawinski, Mike	University of California
Sweet, Ross	Boston University
Tian, Zhiyu	SUNY
Trentacoste, Catherin	Clemson University
Wechter, Matthew	University of Illinois
Whitney, Josh Russell	University of California
Williams, Harold	University of California
Xie, Yu	Purdue University
Yaggie, Jon	San Francisco State University
Zhong, Changlong	University of Southern California
Zhu, Yi	Math Dept

Toric varieties
Held: June 15-26, 2009
The Mathematical Sciences Research Institute

Officially Registered Participant Information
49 participants

Gender (n = 49participants)		
Male	59.18%	29
Female	40.82%	20
Declined to state	0.00%	0

Ethnicity (n = 49 participants)		
White	52.94%	27
Asian	37.25%	19
Hispanic	3.92%	2
Pacific Islander	0.00%	0
Black	0.00%	0
Native American	1.96%	1
Declined to state	3.92%	2

Final Report

MSRI Graduate Summer Workshop

Symplectic and contact geometry and topology

August 2009

Organizers:
J. Etnyre (Georgia Institute of Technology)
D. McDuff (Barnard College)

The goal of this workshop was to introduce a diverse group of students to most of the basic tools used in symplectic and contact geometry and topology, as well as to introduce some of the driving questions that motivate the field today. To accomplish this we had:

1. **six lecture series**, two of them concerning symplectic geometry — an introductory lecture series by Margaret Symington (Mercer University) and a series on capacities and symplectic packing by Dusa McDuff (Columbia University); two of them concerning contact geometry — an introductory lecture series by John Etnyre (Georgia Institute of Technology) and a series of lectures on contact homology by Lenny Ng (Duke University); and two of them concerning holomorphic curve techniques in symplectic and contact geometry — an introductory lecture series by Katrin Wehrheim (MIT) and a series on Floer homology by Ely Kerman (UIUC).

2. **question/problem sessions** where students could ask the lecturers further questions about the material from the lecture series. Following these questions the lecturers would choose 3-5 problems for the students to work on in groups.

3. **break out sessions** where students with weaker backgrounds could meet with the lecturers and TA's to have questions answered about more basic material (in the first week).

4. **four, one hour talks** to give a brief introduction to other topics (in the second week). Three of these talks were on Lagrangian Floer theory, Lagrangian correspondences and quilts, and quantum homology and Gromov–Witten invariants, and given by, respectively, Mark Branson, Sikimeti Ma'u and Dusa McDuff. (The first two of these speakers were also TAs for the program.) The fourth talk was on applications of symplectic geometry and was given by three people Ely Kerman, Sean Fitzgerald (a student in the workshop) and Misha Entov. The topics for these talks were suggested by the more advanced students.

5. **a capstone meeting** at the very end of the program, where various topics that were missed during the program could be discussed and where some of the more advanced students could present their work to everyone. The students that made presentations were Sean Fitzgerald (on geometric quantization), Jonathan Yazinski (on constructions of symplectic 4-manifolds) and Doug LaFountain (Legendrian classification of iterated torus knots).

In addition to the activities specifically planned for the workshop, the last day of the workshop overlapped with the Connections workshop for the Symplectic and Contact Geometry program, and the activities for the two workshops were coordinated during the morning sessions. This allowed the graduate participants to hear an overview talk about Gromov–Witten invariants in symplectic geometry by Eleny-Nicoleta Ionel (Stanford University) and a talk on Generating families by Lisa Traynor (Bryn Mawr). These two lecturers had been thoroughly briefed on the diverse nature of their audience, and managed to find something fresh to say at a good level for everyone. The first talk served the graduate students as a summing up, while the second introduced a completely new (and reasonably elementary) approach to symplectic questions.

Evaluation of the components of the program

The lecturers were chosen for the clarity of their expositions and despite the wildly variable backgrounds of the students, most students seem to get quite a bit out of the lectures. Their enthusiasm and interest in the material stayed high throughout the two weeks. There were comments from the students concerning the tight organization of all the lectures — what was learnt in the first week being used in the second. Immediately following this workshop was the introductory workshop for the year long program in symplectic and contact geometry and topology. Several of the students stayed for this workshop too, and one of them specifically commented that the graduate workshop had beautifully prepared him for the more advanced workshop.

Many students and several lecturers commented that the afternoon question/problem session and the break out sessions were highly successful and really added a great deal to the workshop. In particular, these accommodated the varied background of the participants very well, in that the more advanced students could work with the less advanced students and all get something from the interaction. In addition the break out sessions allowed many students to fill in gaps in their background or really come to grips with some basic examples (for example there were discussions of bundle theory, Chern classes, group actions,...).

The one hour lectures exposed the students to more of the fundamental ideas in the field than could have been done in the lecture series alone. We did not hold any of these talks in the first week as we used the entire afternoon to run the question/problem sessions and break out sessions. This really helped the students focus on the basic material and prepare them for everything in the second week.

The capstone meeting was a good way to end the program. It helped sum up what the students had learned over the previous two weeks, and pointed them towards new ideas and problems.

Students

The students in the program had very diverse backgrounds. An informal servey at the beginning of the program indicated that approximately 1/3 were beginning graduate students (that is, had been in graduate school for about 1 or maybe 2 years) and a little less than 1/3 were advanced (that is within a year or so of graduating). In addition somewhat more than half had some exposure to symplectic geometry before and somewhat less than 1/3 had exposure to contact geometry.

Having students from across the country was a real strong point of the workshop, but the extremely varied backgrounds made it a bit difficult for the lecturers to find the level to aim their lectures. In the future, it might be useful to have the students fill out a survey quite a while before the workshop. That way the lecturers will know exactly what to expect. It might also be possible to break the students into various groups (like advanced but no exposure to subject, beginning student, ...) and send each of the groups an e-mail with suggestions about what they can do to prepare for the workshop so they can get the most out of it (like various background readings). In any event, having this data would be useful in planning the activities of the workshop.

Details on the lecture series

Margaret Symington: Introduction to symplectic geometry. (5 lectures)

The five lectures “Introduction to Symplectic Geometry and Topology” began with some motivating questions and remarkable results to give a bit of context to the material upcoming in this lecture series and others. The first topic was linear symplectic algebra, which culminated in the relations between the symplectic and complex linear groups that imply the equivalence of the classifications of symplectic and complex vector bundles. After a variety of examples of symplectic manifolds were given, including a detailed description of the canonical one-form on any cotangent bundle and the ensuing exact symplectic form, the lack of local invariants near a point or a submanifold was explained. The major topic of the lectures was constructions of symplectic manifolds, focusing on blowingup and the symplectic sum, both explained in terms of symplectic cutting (and hence symplectic reduction). The symplectic sum was then applied in Gompfs proof that every finitely presented group is the fundamental group of some closed symplectic four-manifold. The last lecture was devoted to toric manifolds with an emphasis on dimension four. The toric geometry gave further insight into blowing up and down.

John Etnyre: Introduction to contact geometry. (5 lectures)

In these lectures the basic examples of contact manifolds were presented followed by a proof of various “local theorems” like Darboux’s theorem and Gray’s theorem. We then proved the existence of contact structures on 5-manifolds by using open book decompositions. The last two lectures in the course were an introduction to convex surfaces and culminated in the classification of tight contact structures on solid tori with various boundary conditions.

Katrin Wehrheim: Introduction to holomorphic curves. (5 lectures)

The course on pseudoholomorphic curves was guided by the proof of Gromov’s nonsqueezing theorem. The first lecture introduced the geometric ideas and reduced the proof to the existence of a holomorphic sphere in a certain homology class. The second lecture provided the setup for moduli spaces of pseudoholomorphic curves: The Cauchy-Riemann operator, (non)-integrability of almost complex structures, comparison theorems with holomorphic functions, reparametrization of pseudoholomorphic maps, energy identities. The remaining three lectures introduced the students to the standard tools for analyzing moduli spaces: Fredholm theory for sections of Banach bundles, elliptic regularity for the Cauchy-Riemann operator, transversality for simpe curves, the bubbling phenomenon, and Gromov compactness.

Dusa McDuff: Symplectic embedding problems and capacities. (4 lectures)

The first lecture gave an overview of different ways to make measurements in symplectic topology. We then concentrated on embedding problems for balls and ellipsoids in 4 dimensions. This is an interesting, explicit application of J-holomorphic curve techniques that involves understanding some of the basic facts about symplectic 4-manifolds such as the uniqueness of the symplectic structure on CP^2. It also used toric models and the blowing up process introduced by Symington in the first week.

Lenny Ng: Legendrian knots in contact 3-manifolds (4 lectures)

This lecture series addressed topics in contact geometry and relations to topology. The primary focus was on Legendrian and transverse knots, their classification, and topological applications.Chekanov's differential graded algebra theory for Legendrian knots was used as an introduction to contact homology and combinatorial aspects of holomorphic-curve techniques. The lectures also discussed how bounds on invariants of Legendrian and transverse knots can be applied to topological questions such as the existence of exotic smooth structures on $\mathbb{R}^4$ and the Milnor conjecture for torus knots. Very recent developments in the field were briefly mentioned, particularly the relevance of Heegaard Floer homology to the classification problem for transverse knots.

Ely Kerman: Hamiltonian Floer Theory (4 lectures)

In this lecture series we developed and applied several tools from Hamiltonian Floer theory. In the first two lectures we discussed the properties of Floer trajectories and their moduli spaces, and reviewed the construction of Morse homology for closed manifolds. We then defined Hamiltonian Floer homology for closed aspherical symplectic manifolds and developed some tools which exploit the action filtration of Floer homology. In the last lecture we used these tools to; (re)prove Viterbo's theorem asserting the existence of closed characteristics on hypersurfaces of contact type in symplectic vector spaces, and to (re)establish the existence of the Hofer-Zehnder capacity and hence recover Gromov's Nonsqueezing Theorem.

Conclusion

Both organizers thought the somewhat unusual circumstance of this graduate program (i.e. that it was followed immediately by a workshop for a main program in the same area) worked out very well. Several of the graduate students were able to extend their learning experience by staying for the Introductory Workshop. The direct and indirect feedback the organizers heard from both students and lecturers was uniformly positive, and points to the workshop having been highly successful.

Symplectic and Contact Geometry

Invited Speakers

Traynor, Lisa	Bryn Mawr College
Symington, Margaret Fife	Mercer University
Wehrheim, Katrin	MIT
Kerman, Ely	University of Illinois at Urbana-Champaign
Ng, Lenhard L.	Duke University
Etnyre, John	Georgia Institute of Technology
McDuff, Dusa Margaret	Barnard College

Participant List

MSRI Workshop:

Symplectic and Contact Geometry

August 3-14, 2009

at Mathematical Sciences Research Institute, Berkeley California

Name	Institution
Al-Rawashdeh, Waleed	Central Michigan University
Arima, Emi	University of California
Bao, Erkao	University of Wisconsin
Burke, Jonathan	Wesleyan University
Carneiro, Andre	Columbia University
Espina, Jacqueline	University of California
Fitzpatrick, Sean	University of Toronto
Franklin, Bridget Dawn	Rice University
Georgieva, Penka Vasileva	Stanford University
Gospodinov, Georgi Donev	Olin College of Engineering
Gripp, Vinicius	University of California
Hom, Jennifer Cheung	University of Pennsylvania
Hong, hansol	Seoul National University
Huang, Yang	University of Southern California
Jones, Korri	Howard University
Kaloti, Amey	Georgia Institute of Technology
Kang, Sooran	University of Colorado
Khonggkha, Poranee	University of Cincinnati
Kinlaw, Paul	Dartmouth College
LaFountain, Doug	University at Buffalo (SUNY)
Lanzat, Sergei	Technion---Israel Institute of Technology
Lee, Brandyn	University of North Carolina
Lu, Ni	University of Hawaii at Manoa
Mansaku, Shkelzen	Kansas State University
Mansfield, Laura	Bryn Mawr College
Mesa, Camilo	University of Colorado
Michael, Brandenbursky	Technion
Micklewright, Christopher	Bryn Mawr College
Montgomery, Whitney	University of Georgia
Mossa, Roberto	Istituto Nazionale di Alta Matematica "Francesco Severi"
Nelson, Joanna	University of Wisconsin
Park, Heesang	Seoul National University
Rice, Daniell	Portland State University
Rose, David	Duke University
Rueckriemen, Ralf	Dartmouth College
Sahattchieve, Jordan Antonov	University of Michigan
Schneider, Greg	University of Buffalo
Sealy, Matt	University of Missouri
Shaw, Kristin Marie	University of Toronto
Smith, Aaron	University of Pennsylvania
Tanaka, Hiroaki	Northwestern University
Venugopolan, Sushmita	Rutgers University
Wang, Dongning	University of Wisconsin
Yazinski, Jonathan	Indiana University

Symplectic and Contact Geometry
Held: August 3-14, 2009
The Mathematical Sciences Research Institute

Officially Registered Participant Information
44 participants

Gender (n = 44 participants)		
Male	59.09%	26
Female	34.09%	15
Declined to state	6.82%	3

Ethnicity (n = 37 participants)		
White	59.46%	22
Asian	35.14%	13
Hispanic	5.41%	2
Pacific Islander	0.00%	0
Black	0.00%	0
Native American	0.00%	0
Declined to state	0.00%	0

Example of a Summer Graduate Workshop Report

Random Matrix Theory

July 6-17, 2009

Organizers

- Jinho Baik (University of Michigan)
- Percy Deift (New York University)
- Toufic Suidan (University of Arizona)
- Brian Rider (University of Colorado)

The MSRI summer graduate workshop on Random Matrix theory, organized by Jinho Baik of University of Michigan, Percy Deift of New York University, Brian Rider of University of Colorado and Toufic Suidan of University of Arizona, took place from July 6 to July 17, 2009. There were 40 participants with diverse backgrounds within mathematics and physics. Some of the participants were first year graduate students with no background in random matrix theory while others were upper-level graduate students already working in the field.

Random matrix theory is a highly interdisciplinary field. The topics studied, and the tools used, arise from many areas in mathematics, including analysis, probability, combinatorics and mathematical physics. Each of these disciplines brings a unique insight and a unique set of techniques to random matrix theory. The multi-disciplinary nature of the discipline has been highly fruitful in the development of the field, but at the same time, it presents a daunting obstacle to newcomers who wish to enter the field. The workshop was intended to overcome this obstacle by providing several basic lectures on different aspects of random matrix theory. There were a total of 8 sets of lecture series, each ranging from 3 to 5 hours, by 8 different speakers (Persi Diaconis, Alice Guionnet, Alexander Its, Peter Miller, Craig Tracy, Jinho Baik, Percy Deift and Brian Rider). Most lecturers emphasized their particular view of random matrix theory, but at the same time, several important themes/methods (such as determinantal structure and integrable structure) were covered by multiple speakers. The goal was to give the students a basic familiarity with concepts utilized in different approaches to random matrix theory and which will be helpful to the students who will participate in the main semester program in random matrix theory in the fall of 2010.

The typical daily schedule consisted of 4 lectures and an hour-long problem session. The problem sessions were lead by two very able TA's, Antonio Auffinger and Ivan Corwin from New York University. They usually went over a few difficult points in lectures on the same day, and solved exercises that were given during the lectures. The problem sessions turned out to be very helpful to students. One comment from the survey says

Example of a Summer Graduate Workshop Report

``Give Ivan and Tuca a raise. This got me past the first week. ‘’ At the end of the workshop, the TA’s distributed a 35-page note that included summaries of all the lectures and the exercises the speakers posted during the lectures. This will hopefully be an aide to students as they review what they learned during the workshop. One of the problem sessions was devoted to discussing open problems in random matrix theory, as requested by many students during the workshop.

Many of the participants seem to have enjoyed the opportunity to be exposed to the many aspects of random matrix theory. However, it is unfortunate that some of graduate students who wished to participate in the workshop were turned down due to the lack of space. Some of these students were at the beginning of their studies in random matrix theory, and could have benefitted from the workshop enormously. On the other hand, some of the participants in the workshop, unfortunately, were not particularly motivated in the field. It would have been helpful if the organizers were involved in the participant selection process. Many of the students who were excluded were students of the organizers of the semester program in random matrix theory in the fall of 2010.

Some positive comments from participants are:

* I was introduced to a field that is close to my research to a good degree of depth. I learned a number of interesting techniques, some of them directly, from the people who first came up with them or with their most important applications. I met other people with similar interests and with expertise in areas that are complementary to the ones I know well and this may further future collaborations.

* This workshop presented a nice picture of the problems of inherent in random matrix theory, and also pave a good taste for the techniques that have been used to attack them. Completely worth my time!

Some other comments are:

* Needed more time devoted to applications

* Sometimes a recap of the "big picture" would have been nice.

Lectures from the workshop are available on streaming video at the MSRI website, http://www.msri.org/calendar/sgw/WorkshopInfo/485/show_sgw.

MSRI Mathematical Sciences Research Institute

Random Matrix theory

July 6, 2009 to July 17, 2009

Schedule

Monday July 6, 2009		
9:30AM – 10:30AM	Percy Deift	**Invariant matrix ensembles: basic theory**
11:00AM – 12:00PM	Jinho Baik	Random Permutations
12:00PM - 02:00PM	Lunch	
02:00PM - 03:00PM	Persi Diaconis	**What the heck is Haar measure?**
03:00PM - 03:30PM	Coffee, tea in the atrium	
03:30PM – 4:30PM	Problem Session	
Tuesday July 7, 2009		
9:30AM – 10:30AM	Percy Deift	Invariant matrix ensembles: basic theory
11:00AM – 12:00PM	Jinho Baik	Random Permutations
12:00PM - 02:00PM	Lunch	
02:00PM - 03:00PM	Persi Diaconis	**The four classical groups U(n), O(n), Sp(n), and Sn**
03:00PM - 03:30PM	Coffee, tea in the atrium	
03:30PM – 4:30PM	Problem Session	
Wednesday July 8, 2009		
9:30AM – 10:30AM	Percy Deift	Invariant matrix ensembles: basic theory
11:00AM – 12:00PM	Jinho Baik	Random Permutations
12:00PM - 02:00PM	Lunch	
02:00PM - 03:00PM	Persi Diaconis	**Applications, Extensions and Questions**
03:00PM - 03:30PM	Coffee, tea in the atrium	
03:30PM – 4:30PM	Brian Rider	Beta ensembles and Edelman-Sutton conjectures
Thursday July 9, 2009		
9:30AM – 10:30AM	Percy Deift	Invariant matrix ensembles: basic theory
11:00AM – 12:00PM	Jinho Baik	Random Permutations
12:00PM - 02:00PM	Lunch	
02:00PM - 03:00PM	Brian Rider	**The general beta soft edge**
03:00PM - 03:30PM	Coffee, tea in the atrium	
03:30PM – 4:30PM	Problem Session	
Friday July 10, 2009		
9:30AM – 10:30AM	Percy Deift	Invariant matrix ensembles: basic theory
11:00AM – 12:00PM	Brian Rider	**Hard edge and transition**
12:00PM - 1:300PM	Lunch	
01:30PM - 02:30PM	Brian Rider	**Bulk limits and open problems**
03:00PM – 04:00PM	Problem Session	
4:00PM – 4:30PM	Coffee, tea in the atrium	
Monday July 13, 2009		
9:30AM – 10:30AM	Alexander Its	**Painleve Equations. The Riemann-Hilbert point of view**
11:00AM – 12:15PM	Alice Guionnet	**Wigner matrices; global asymptotics and combinatorics of moments**
12:15PM – 2:00PM	Lunch	
2:00PM - 3:00PM	Peter Miller	Unitary Ensembles and Orthogonal Polynomials
3:00PM – 3:30PM	Coffe, tea in the atrium	
3:30PM – 4:30PM	Problem Session	
Tuesday July 14, 2009		
9:30AM – 10:30AM	Alexander Its	**Painleve Equations. The Riemann-Hilbert point of view**
11:00AM – 12:15PM	Alice Guionnet	**Wigner matrices; global asymptotics and combinatorics of moments**
12:15PM – 2:00PM	Lunch	
2:00PM - 3:00PM	Peter Miller	Riemann-Hilbert Problems: Theory and Solution Techniques
3:00PM – 3:30PM	Coffe, tea in the atrium	
3:30PM – 4:30PM	Problem Session	
Wednesday July 15, 2009		
9:30AM – 10:30AM	Alexander Its	**Painleve Equations. The Riemann-Hilbert point of view**
11:00AM – 12:15PM	Alice Guionnet	**Wigner matrices; global asymptotics and combinatorics of moments**
12:15PM – 2:00PM	Lunch	
2:00PM - 3:00PM	Craig Tracy	**The asymmetric simple exclusion model: Integrable structure and limit theorems**
3:00PM – 3:30PM	Coffe, tea in the atrium	
3:30PM – 4:30PM	Problem Session	
Thursday July 16, 2009		
9:30AM – 10:30AM	Peter Miller	Asymptotic Analysis of Orthogonal Polynomials I
11:00AM – 12:00PM	Craig Tracy	The asymmetric simple exclusion model: Integrable structure and limit theorems
12:00PM – 2:00PM	Lunch	
2:00PM - 3:00PM	Craig Tracy	The asymmetric simple exclusion model: Integrable structure and limit theorems
3:00PM – 3:30PM	Coffe, tea in the atrium	
3:30PM – 4:30PM	Problem Session	
Friday July 17, 2009		
9:30AM – 10:30AM	Peter Miller	Asymptotic Analysis of Orthogonal Polynomials II
11:00AM – 12:00PM	Alexander Its	**Painleve Equations. The Riemann-Hilbert point of view**
12:00PM – 2:00PM	Lunch	
2:00PM – 3:00PM	Problem Session	
3:00PM – 3:30PM	Coffe, tea in the atrium	

Currently Available Videos

- **Percy Deift**, Invariant matrix ensembles: basic theory 5 *July 10,2009, 09:30 AM to 10:30 AM*
- **Brian Rider**, Hard edge and transition *July 10,2009, 11:00 AM to 12:00 PM*
- **Brian Rider**, Bulk limits and open problems *July 10,2009, 01:30 PM to 02:30 PM*
- **Alexander Its**, Painleve Equations: The Riemann-Hilbert point of view *July 13,2009, 09:30 AM to 10:30 AM*
- **Alice Guionnet**, Wigner Matrices; Global Asymptotics and Combinatorics of Moments *July 13,2009, 11:00 AM to 12:15 PM*
- **Peter Miller**, Unitary Ensembles and Orthogonal Polynomials *July 13,2009, 02:00 PM to 03:00 PM*
- **Alexander Its**, Painleve Equations. The Riemann-Hilbert Point of View *July 14,2009, 09:30 AM to 10:30 AM*
- **Alice Guionnet**, Wigner Matrices; Global Asymptotics and Combinatorics of Moments *July 14,2009, 11:00 AM to 12:15 PM*
- **Peter Miller**, Riemann-Hilbert Problems: Theory and Solution Techniques *July 14,2009, 02:00 PM to 03:00 PM*
- **Alexander Its**, Painleve Equations. The Riemann-Hilbert Point of View *July 15,2009, 09:30 AM to 10:30 AM*
- **Alice Guionnet**, Wigner Matrcies; Global Asymptoics and Combinatorics of Moments *July 15,2009, 11:00 AM to 12:15 PM*
- **Craig Tracy**, The Asymmetric Simple Exclusion Model: Integrable Structure and Limit Theroms *July 15,2009, 02:00 PM to 03:00 PM*
- **Peter Miller**, Asymptotic Analysis of Orthogonal Polynomials I *July 16,2009, 09:30 AM to 10:30 AM*
- **Craig Tracy**, The Asymmetric Simple Exclusion Model: Integrable Structure and Limit Theorems *July 16,2009, 02:00 PM to 04:00 PM*
- **Peter Miller**, Asymptotic Analysis of Orthogonal Polynomials II *July 17,2009, 09:30 AM to 10:30 AM*
- **Alexander Its**, Painleve Equations. The Riemann-Hilbert Point of View *July 17,2009, 11:00 AM to 12:15 PM*
- **Percy Deift**, Invariant matrix ensembles: basic theory *July 6,2009, 09:30 AM to 10:30 AM*
- **Jinho Baik**, Random Permutations *July 6,2009, 11:00 AM to 12:00 PM*
- **Jinho Baik**, Random Permutations 2 *July 6,2009, 02:00 PM to 03:00 PM*
- **Percy Deift**, Invariant matrix ensembles: basic theory 2 *July 7,2009, 09:30 AM to 10:30 AM*
- **Persi Diaconis**, What the heck is Haar measure? *July 7,2009, 11:00 AM to 12:00 PM*
- **Persi Diaconis**, The four classical groups U(n), O(n), Sp(n), and Sn *July 7,2009, 02:00 PM to 03:00 PM*
- **Percy Deift**, Invariant matrix ensembles: basic theory 3 *July 8,2009, 09:30 AM to 10:30 AM*
- **Jinho Baik**, Random Permutations 3 *July 8,2009, 11:00 AM to 12:00 PM*
- **Persi Diaconis**, Applications, Extensions and Questions *July 8,2009, 02:00 PM to 03:00 PM*
- **Brian Rider**, Beta ensembles and Edelman-Sutton conjectures *July 8,2009, 03:30 PM to 04:30 PM*
- **Percy Deift**, Invariant matrix ensembles: basic theory 4 *July 9,2009, 09:30 AM to 10:30 AM*
- **Jinho Baik**, Random Permutations 4 *July 9,2009, 11:00 AM to 12:00 PM*
- **Brian Rider**, The general beta soft edge *July 9,2009, 02:00 PM to 03:00 PM*
- **Alexander Its**, Painleve Equations: The Riemann-Hilbert point of view *June 13,2009, 09:30 AM to 10:30 AM*

Random Matrix Theory
Held: July 6 - 17, 2009
The Mathematical Sciences Research Institute

Officially Registered Participant Information
36 participants

Gender (n = 36 participants)		
Male	75.00%	27
Female	19.44%	7
Declined to state	5.56%	2

Ethnicity (n = 34 participants)		
White	61.76%	21
Asian	23.53%	8
Hispanic	5.88%	2
Pacific Islander	0.00%	0
Black	2.94%	1
Native American	0.00%	0
Declined to state	5.88%	2

Random Matrix Theory

Invited Speakers

Name	Institution
Baik, Jinho	University of Michigan
Deift, Percy	NYU Courant Institute
Diaconis, Persi	Stanford University
Guionnet, Alice	Ecole Normale Superieure de Lyon
Its, Alexander	IUPUI
Miller, Peter	University of Michigan
Rider, Brian	University of Colorado at Boulder
Suidan, Toufic	University of California, Santa Cruz
Tracy, Craig	University of California, Davis

Participant List

MSRI Workshop:

Random Matrix Theory

July 6 - 17, 2009

at Mathematical Sciences Research Institute, Berkeley California

Name	Institution
Abduvalieva, Gulnara	Drexel University
Al-Sharadqah, Ali	University of Alabama at Birmingham
Ampadu, Clement	Central Michigan University
Antonioli, John	University of British Columbia
Aristoff, David	University of Texas
Barber, John	Johns Hopkins University
Bloemendal, Alex	University of Toronton
Dahl, Janina	Rice University
De La Iglesia, Manuel	New York University
Hajij, Mustafa	Louisiana State University
Holmes, Irina	Louisiana State University
Janoski, Janine	Clemson University
Jenkinson, Justin	Case Western Reserve University
Lee, Eunghyun	University of California, Davis
Liechty, Karl	Purdue University
Liu, Zhipeng	University of Michigan
Maltsev, Anna	California Institute of Technology
Matayoshi, Jeff	University of California, Irvine
Melborne, James	University of Kansas
Mitkovski, Misko	Texas A & M University
Morales, Pedro	Baylor University
Noyes, Mike	University of Colorado
O'Rourke, Sean	University of California, Davis
Oyoung, Josh	University of California, Davis
Prager, David	University of Georgia
Rael, Michael	University of California, Irvine
Rios Zertuche, Rodolfo	Princeton University
Rivasplata, Omar	University of Alberta
Spektor, Susanna	University of Alberta
Sun, Chung-Kai	University of California, Davis
Vaidyanathan, chandra	University of Missouri
Xu, Zhe	Northwestern University
Xu, Zhengjie	University of Michigan
Yang, Yuting	University of Michigan
Zemlyanova, Anna	Louisiana State University
Zhi, Weifeng	University of Kentucky

Inverse Problems

Gunther Uhlmann, University of Washington

Inverse Problems are problems where causes for a desired or an observed effect are to be determined. They lie at the heart of scientific inquiry and technological development. Applications include a number of medical as well as other imaging techniques, location of oil and mineral deposits in the earth's substructure, creation of astrophysical images from telescope data, finding cracks and interfaces within materials, shape optimization, model identification in growth processes and, more recently, modelling in the life sciences.

The workshop consisted of 8 minicourses addressing a broad range of the theoretical and practical issues arising in inverse problems including boundary rigidity and travel time tomography, cloaking and invisibility, electrical impedance imaging, statistical methods and biological applications, thermoacoustic and x-ray tomography, and resonances. The minicourses also included computer labs and/or problem sessions in which the students participated actively in learning the material taught in the minicourses.

All the mini-courses were enthusiastically attended by the participants and drew many questions and discussions during and between the lectures in the computer labs and the problem sessions. The graduate students participating were presented a wide panorama of inverse problems topics, mathematical techniques, applications, and outstanding challenges.

Below is the list of the minicourses with a brief description.

- **Discrete Models for Electrical Impedance Tomography**

  Lecturers: Liliana Borcea (Rice University) and Fernando Guevara Vasquez (University of Utah)

  Discrete network models for the inverse problem of electrical impedance tomography were discussed. These models can be motivated by physical arguments, such as flow channeling in high contrast media, or by computational model reduction approaches. The lectures discussed both cases.

  a) It was shown that in high contrast media, with rapidly fluctuating conductivity that takes very large and very small values in the domain of the solution, the Dirichlet to Neumann map degenerates to the map of a resistor network. This has significant impact on the inverse problem, including the fact that the conductivity may not be determined uniquely by the data. Also numerical approaches were discussed for such high contrast inverse problems.

  b) Network models for low contrast electrical impedance tomography can be motivated by model reduction. Inversion methods were considered, where the reduced models are resistor networks that arise in finite volume discretizations of the elliptic partial differential equation satisfied by the electric potential, on adaptive grids that are computed as part of the problem. It was shown that the networks are uniquely defined by a broad class of measurements of the Dirichlet-to-Neumann map in two dimensions. The size of the networks is limited by the precision of the measurements. The resulting grids are naturally refined near the boundary, where it is measured and where better resolution of the images are expected. Then, it was shown how to use the networks to estimate the continuum conductivity function. Computer labs illustrated the concepts described in this minicourse.

- **Dynamic Inverse Problems in Cell Biology Using Bayesian Framework**

  Lecturers: Daniela Calvetti (Case Western Reserve) and Erkki Somersalo (Case Western Reserve)

Below is the list of topics considered in this minicourse.

1. Introduction: Examples of dynamic inverse problems from biological models
2. Stochastic models as expression of uncertainty. Probabilities and densities
3. Probability densities, samples and histograms
4. Propagation of probability densities, propagation of uncertainties
5. Updating densities using data. Resampling
6. Bayesian filtering

Each lecture was accompanied by computational examples and exercises that the students were encouraged to solve with Matlab.

- **An Introduction to the Calderón Problem**

  Oleg Imanuvilov (Colorado State University) and Gunther Uhlmann (University of Washington)

  In this minicourse it was considered the problem of determining a complex-valued potential q in a bounded two dimensional domain from the Cauchy data measured on an arbitrary open subset of the boundary for the associated Schrödinger equation $\Delta + q$. A motivation comes from the classical inverse problem of electrical impedance tomography problem. In this inverse problem one attempts to determine the electrical conductivity of a body by measurements of voltage and current on the boundary of the body. This problem was proposed by Calderón and is also known as Calderón's problem. It was also discussed the case where the electrical measurements were made on part of the boundary. There were problem sessions for this and the related minicourse of Lassi Päivärinta and Mikko Salo on the two dimensional case.

- **Transforms of Radon Type in Computed Tomography**

  Lecturers: Peter Kuchment (Texas A&M) and Leonid Kunyansky (University of Arizona)

  The mini-course was devoted to some areas of mathematics underlying many contemporary methods of medical, industrial, and geophysical imaging. More specifically, the integral geometric transforms and their applications in medical (as well as industrial and geophysical) imaging were studied. The main emphasis was on the X-ray transform that integrates a function over lines, Radon transform (integrating functions over hyperplanes) and their weighted and curvilinear versions (e.g., integrals over certain sets of circles or spheres). The issues of uniqueness of reconstruction of a function from its transform, inversion formulas, stability of inversion, incomplete data issues, etc. were addressed. It was also shown how these transforms arise and are applied in the X-ray CAT scan, MRI, emission tomography, and some novel imaging methods, such as thermoacoustics.i the students worked on computer labs using matlab programs.

- **The Calderón Problem; the Two Dimensional Case**

  Lecturers: Lassi Päivärinta (U. Helsinki) and Mikko Salo (U. Helsinki)

  Abstract: The recent developments mathematical theory of electrical impedance tomography in the two dimensional case were discussed. This was a follow up to the minicourse by O. Imanuvilov and G. Uhlmann that gave an introduction to the problem and discussed the three dimensional problem. The applications of EIT include monitoring heart and lungs of unconscious patients, detecting pulmonary edema and enhancing ECG and EEG. In two dimensions the tools of complex analysis come handy. Especially methods of analytic and quasi-conformal mappings turn out to be central and some of them were presented in the lectures.

- **Invisibility and Inverse Problems**

  Lecturers: Matti Lassas (Helsinki University of Technology) and Gunther Uhlmann (University of Washington)

  Recent theoretical and experimental progress on making objects invisible to detection by electromagnetic waves were described. Ideas for devices that would have once seemed fanciful may now be at least approximately implemented physically using a new class of artificially structured materials called *metamaterials*. Maxwell's equations have transformation laws that allow for design of electromagnetic material parameters that steer light around a hidden region, returning it to its original path on the far side. Not only would observers be unaware of the contents of the hidden region, they would not even be aware that something was being hidden. The object, which would have no shadow, is said to be *cloaked*. Proposals for, and even experimental implementations of, such cloaking devices have received the most attention, but other designs having striking effects on wave propagation are possible. All of these designs are initially based on the transformation laws of the equations that govern wave propagation but, due to the singular parameters that give rise to the desired effects, care needs to be taken in formulating and analyzing physically meaningful solutions. The recent history of the subject was recounted and some of the mathematical and physical issues involved were discussed, especially for the case of EIT.

- **Integral Geometry of Tensor Fields and the Inverse Kinematic Problem**

  Lecturer: Plamen Stefanov (Purdue University)

  The main topic of this mini-course was the inverse kinematic problem (also known as the lens rigidity problem) and its linearization that leads to integral geometry problems for tensor fields. Let (M, g) be a compact Riemannian manifold with boundary. Given a boundary point $x \in \partial M$ and an incoming unit vector ξ at x, let $y \in \partial M$ be the (first) exit point of the geodesics issued from (x, ξ), and let η be its direction. Let $\ell(x, \xi)$ be the length of this geodesic. We define the scattering relation σ by setting $(y, \eta) = \sigma(x, \xi)$. The inverse kinematic problem asks whether (σ, ℓ) determine uniquely the metric g, up to a group of diffeomorphisms fixing the boundary. The closely related boundary rigidity problem is to determine g from the distance function restricted to $\partial M \times \partial M$. Those problems arise naturally in the inverse problems theory of hyperbolic PDEs, and are also of independent interest in geometry. They were first studied in an attempt to recover the inner structure of the Earth from the travel times of seismic waves.

  A linearization of this problem leads to the following integral geometry problem: Can we recover a symmetric 2-tensor field f_{ij} from its integrals

  $$If(\gamma) = \int f_{ij}(\gamma(t))\dot{\gamma}^i(t)\dot{\gamma}^j(t)\, dt$$

  along all geodesics in M connecting boundary points? Such a recovery can only be possible up to a potential field dv, where d is the symmetrized covariant derivative, and v is any 1-form vanishing on ∂M. We will start with the linear problem emphasizing a microlocal point of view. We will show that I^*I is a pseudo-differential operator (ΨDO), elliptic on the complement of the potential tensors. The problem was reduced to a Fredholm one, to show that it is solvable for a class of metrics, and to prove stability estimates. We will also use analytic microlocal analysis to prove injectivity. Related integral geometry problems were discussed, too. It was shown how one can apply the results about the linear problem to obtain local uniqueness and stability estimates for the inverse kinematic problem. The student worked on problems during problem sessions in this minicourse.

- **Resonances**

  Lecturer: Maciej Zworski (UC Berkeley)

  The minicourse provided an introduction to the mathematical theory of quantum resonances from the microlocal point of view. The basis concepts of semiclassical/microlocal analysis were reviewed.

  The topics included were.

  1. Resonances in one dimension: trace formulae, asymptotic distribution, complex scaling, the Breit-Wigner formula.

  2. Illustration of the theoretical results using MATLAB codes following:

  `http://www.cims.nyu.edu/ dbindel/resonant1d/`,

  stressing the remarkable agreement of semiclassical asymptotics with the low energy numerical results.

  3. A review of semiclassical upper bounds on the number of resonances: the general case and the case of hyperbolic trapped sets. A discussion of recent numerical and experimental investigations of fractal Weyl laws for resonances in different settings.

Inverse Problems

Invited Speakers

Oksanen, Lauri	Helsinki School of Economics
Borcea, Liliana	Rice University
Calvetti, Daniela	case western reserve university
Guevara, Fernando	University of Utah
Imanuvilov, Oleg	Colorado State University
Kuchment, Peter	Texas A&M University
Kunyansky, Leonid	University of Arizona
Lassas, Matti	University of Helsinki
Päivärinta, Lassi	University of Helsinki
Salo, Mikko	University of Helsinki
Somersalo, Erkki Jaakko	Case Western Reserve University
Stefanov, Plamen	Purdue University
Zworski, Maciej	University of California, Berkeley
Holman, Sean	University of Washington
Uhlmann, Gunther	University of Washington

Participant List

MSRI Workshop:

Inverse Problems

July 20-31, 2009

at Mathematical Sciences Research Institute, Berkeley California

Name	**Institution**
Agostiniani, Virginia	Istituto Nazionale di Alta Matematica "Francesco Severi"
Chang, Eun	Virginia Polytechnic Institute and State University
Chung, Francis	University of Chicago
Dai, Mimi	University of California
D'Elia, Marta	Emory University
Diefenthaler, Kamala	University of South Carolina
Dyatlov, Semyon	University of California
Ettinger, Boris	University of California
Fan, Ying Wai	Emory University
Georgieva-Hristova, Yulia	Texas A & M University
Graf, Tobias	Emory University
Hezari, Hamid	Johns Hopkins University
Hoang, Nguyen	Kansas State University
Homa, Laura	Case Western Reserve University
Hoogeboom, Chris	University of Massachusetts
Hora, Raphael	Purdue University
Hubenthal, Mark	University of Washington
Jafarov, Elchin	University of Alaska Fairbanks
Jordan-squire, Christopher	Washington University
Jordan, Daniel	Drexel University
Kilgore, Kimberly	Drexel University
LaRussa, Annette	University of Alabama at Birmingham
Lin, Junshan	Michigan State University
Lin, Min-Hsiung	North Carolina State University
Mamonov, Alexander	Rice University
Marazzi, Leonardo	Purdue University
McGivney, Debra	Case Western Reserve University
Oh, Seougly	University of Kansas
Oksanen, Lauri	University of Helsinki
Osorio, Mauricio	University of Cincinnati
Ozer, Ahmet	Iowa State University
Rivas, Ivonne	University of Cincinnati
Seeluangsawat, Paisa	University of South Carolina
Song, Lei	University of Illinois
Srinivalamurthy, Suresh	Kansas State University
Steinhauer, Dustin	University of California, Los Angeles
Sun, Chung-Kai	University of California, Davis
Taylor, Justin	University of Kentucky
VanValkenburgh, Michael	University of California, Berkeley
Weir, Brad	University of Arizona
Ylinen, Laury	University of Washington
Zhou, Ting	Unversity of Washington

Inverse Problems
Held: July 20-31, 2009
The Mathematical Sciences Research Institute

Officially Registered Participant Information
42 participants

Gender (n = 42 participants)		
Male	69.05%	29
Female	30.95%	13
Declined to state	0.00%	0

Ethnicity (n = 42 participants)		
White	59.52%	25
Asian	28.57%	12
Hispanic	7.14%	3
Pacific Islander	0.00%	0
Black	2.38%	1
Native American	0.00%	0
Declined to state	2.38%	1

Mathematical Sciences Research Institute

The Arithmetic of L-Functions
IAS/PCMI Summer Workshop

June 28, 2009 to July 18, 2009

Salt Lake City, UT, USA

IAS/PCMI Summer Workshop: The Arithmetic of L-Functions

June 28, 2009 to July 18, 2009

Organized by: Cristian Popescu (University of California, San Diego), Karl Rubin (University of California, Irvine), Alice Silverberg (University of California, Irvine)*

The Graduate Summer School bridges the gap between a general graduate education in mathematics and the specific preparation necessary to do research on problems of current interest. In general, these students will have completed their first year, and in some cases, may already be working on a thesis. While a majority of the participants will be graduate students, some postdoctoral scholars and researchers may also be interested in attending.

Prerequisite is a course in algebraic number theory, or equivalent. Familiarity with the language and methods of algebraic geometry would also be helpful for some of the courses.

The main activity of the Graduate Summer School will be a set of intensive short lectures offered by leaders in the field, designed to introduce students to exciting, current research in mathematics. These lectures will not duplicate standard courses available elsewhere. Each course will consist of lectures with problem sessions. Course assistants will be available for each lecture series. The participants of the Graduate Summer School meet three times each day for lectures, with one or two problem sessions scheduled each day as well.

Course Titles and Descriptions:

The 2009 Summer Session in Arithmetic of L-functions will consist of eight graduate level lecture series. On any day during the summer session, three lectures will be offered. Graduate students are asked to attend the lectures as well as two daily problem sessions associated with the lecture and led by a graduate TA.

Benedict Gross, Harvard University

Introduction to the Birch and Swinnerton-Dyer Conjecture

These lectures will give an overview of the Birch and Swinnerton-Dyer conjecture, which relates the L-function of an elliptic curve at s=1 to arithmetic information about the curve. We will formulate the conjecture, discuss the current state of progress on it, and describe some methods for attacking it.

John Tate, University of Texas-Austin

Introduction to Stark's Conjectures

The conjectures concern the leading term $c(\chi)s^{r(\chi)}$ of the Taylor expansion at $s=0$ of the Artin L-function $L(s,\chi,K/k)$ attached to a character χ of the Galois group G of a finite Galois extension K/k of number fields. In the case of the zeta function $(K=k, \chi=1)$, the coefficient $c(\chi)$ is given by the so-called class number formula. Stark's great achievement in the 1970's was to give an analogue for an arbitrary L-function. After some background material on group representations and L-functions I will explain Stark's original conjectures, some analogues, and the enormous amount of evidence for them, theoretical and computational. Most of what I say is in my book "Les conjectures de Stark sur les fonctions L d'Artin en $s=0$".

David Burns, King's College London and Guido Kings, UniversitäRegensburg

The Equivariant Tamagawa Number Conjecture

This is a course on the Equivariant Tamagawa Number Conjecture (ETNC) for Dirichlet L-functions and L-functions associated to elliptic curves.The course will focus on:

1. stating the conjecture;
2. presenting evidence in support of the conjecture;
3. proving that the integral and p-adic refinements of Stark's Conjecture (a la Rubin and Gross) are consequences of the ETNC for Dirichlet L-functions and that the Birch and Swinnerton-Dyer Conjecture is a consequence of the ETNC for L-functions associated to elliptic curves.

Manfred Kolster, McMaster University and Cristian Popescu, University of California-San Diego

Integral Abelian Stark-type Conjectures

Topics:

1. Integral refinements of Stark's Conjecture for abelian L-functions of arbitrary order of vanishing at s=0 and consequences.
2. p-adic refinements of Stark's Conjecture for abelian L-functions and consequences.
3. The conjectures of Lichtenbaum and Coates-Sinnott on special values of abelian L-functions at negative integers.
4. An equivariant main conjecture in Iwasawa theory and consequences.

David Rohrlich, Boston University

Root Numbers

After a general survey of L-functions, functional equations, and epsilon factors, we shall focus on the connections between root numbers and the arithmetic of elliptic curves. Some attention will be paid throughout to the relevant issues in the representation theory of finite groups.

Karl Rubin, University of California-Irvine

Euler Systems

Euler systems were introduced by Kolyvagin as a new tool for bounding the size of ideal class groups and Selmer groups, and for relating the sizes of those groups to special values of L-functions. In this course we will describe the basic Euler system machinery, and apply it in the fundamental cases of cyclotomic fields (class number formulas) and elliptic curves (the Birch and Swinnerton-Dyer conjecture).

Douglas Ulmer, University of Arizona

The Birch and Swinnerton-Dyer Conjecture over Function Fields

We know a lot more about ranks of elliptic curves and the conjecture of Birch and Swinnerton-Dyer over function fields than we do over number fields. I plan to discuss how one can prove special cases of the the BSD conjecture over function fields as well as how one can construct elliptic curves with large Mordell-Weil groups. Much of this also applies to higher dimensional Jacobians. The lectures should be accessible to anyone with a first course in algebraic geometry and some acquaintance with elliptic curves.

Vinayak Vatsal, University of British Columbia

Complex Multiplication and Heegner Points

We will start by discussing the Kronecker-Weber theorem, which gives a description of the abelian extensions of the rational numbers in terms of points of finite order on the circle group. We then move to the theory of complex multiplication, which gives an analogous description of the abelian extensions of imaginary quadratic fields in terms of point of finite order on certain special elliptic curves, the so called CM elliptic curves. From this we move on to Heegner points, namely, the points on modular curves associated to these CM elliptic curves. We will discuss their basic properties, and some of their surprising applications to number fields and the arithmetic of all elliptic curves. If time permits, we will discuss some of the many generalizations of CM points to higher dimensions, other number fields, and p-adic settings.

Participants in the Graduate Summer School also may wish to become involved in the Undergraduate Summer School, attend parts of the Research Program, or participate in the programs of the Education component. Graduate students are expected to participate in Institute-wide activities such as the "Cross Program Activities" and may be asked to contribute some time to volunteer projects related to running the Summer Session.

A limited number of graduate students who have not completed the basic courses may attend. These students will attend some graduate level courses and may be involved as teaching assistants in other programs or work as audio-visual assistants.

Mathematical Sciences Research Institute

Computational Theory of
Real Reductive Groups

July 20, 2009 to July 24, 2009

University of Utah

Salt Lake City, UT, USA

Computational Theory of Real Reductive Groups

Location: University of Utah, Salt Lake City, Utah
July 20, 2009 to July 24, 2009
Organized by: Jeffrey Adams (University of Maryland), Peter Trapa (University of Utah), Susana Salamanca (New Mexico State University), John Stembridge (University of Michigan)*

The structure of real reductive algebraic groups is controlled by a remarkably simple combinatorial framework, generalizing the presentation of Coxeter groups by generators and relations. This framework in turn makes much of the infinite-dimensional representation theory of such groups amenable to computation.

The Atlas of Lie Groups and Representations project is devoted to looking at representation theory from this computationally informed perspective. The group (particularly Fokko du Cloux and Marc van Leeuwen) has written computer software aimed at supporting research in the field and at helping those who want to learn the subject.

The workshop explored this point of view in a lecture series aimed especially at graduate students and postdocs with only a modest background (such as the representation theory of compact Lie groups).

Topics included:

* background on infinite dimensional representations of real reductive groups;
* geometry of orbits of symmetric subgroups on the flag variety;
* Kazhdan-Lusztig theory;
* approaches to the classification of unitary representations;
* geometry of the nilpotent cone.

The workshop was followed by a conference entitled Representation Theory of Real Reductive Groups.